



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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Bruker Nano Analytics, Berlin - Germany

And

Camila Torres

Geóloga, Mineralogia Automatizada, Geometalurgia, Vale Base Metals, Brasil

Presenters



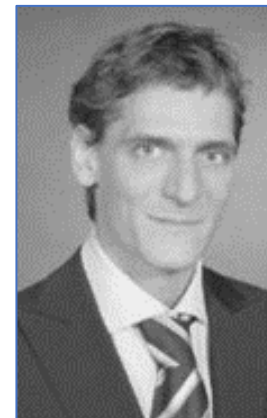
Camila Torres

Geóloga | Mineralogia Automatizada | Geometalurgia
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Sr. Applications Scientist
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04 Geological Samples Analysis and Workflow

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05 Summary and Conclusion, Questions and Answers

03 Greenfield and Brownfield Mining Exploration Projects in Brasil



WEBINAR: Greenfield and Brownfield Mining Exploration Projects

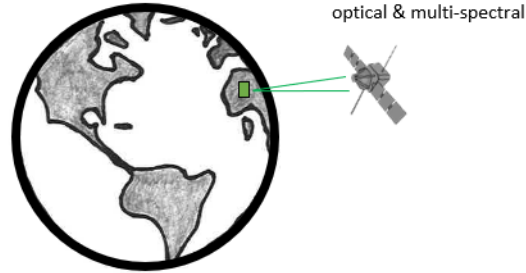
Micro-XRF Imaging in Geological Sciences – Capabilities, Applications and Examples

Introduction

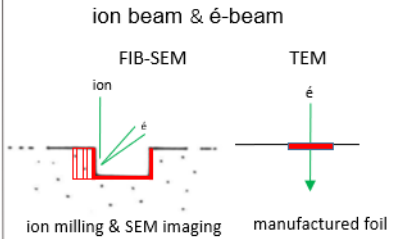
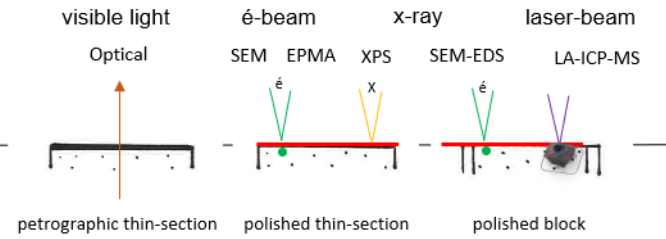
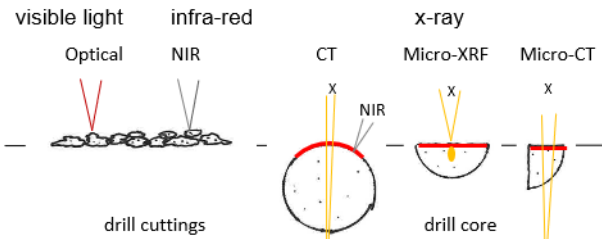
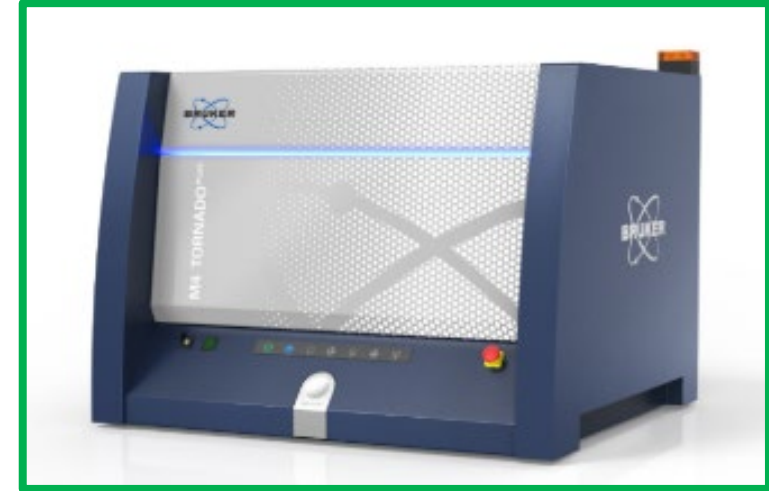
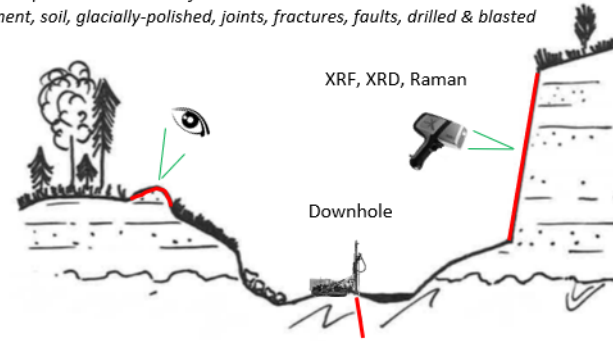
Overview: Characterization Workflow of a multiscale approach

Micro-XRF M4 TORNADO PLUS

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



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



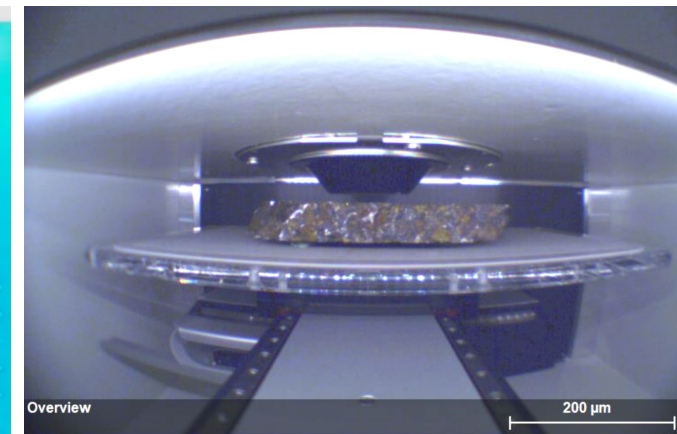
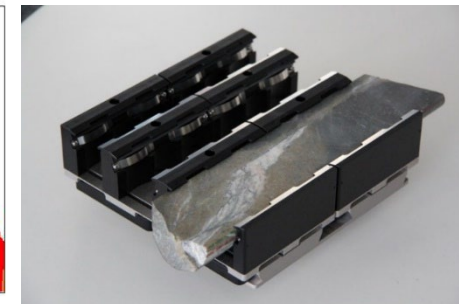
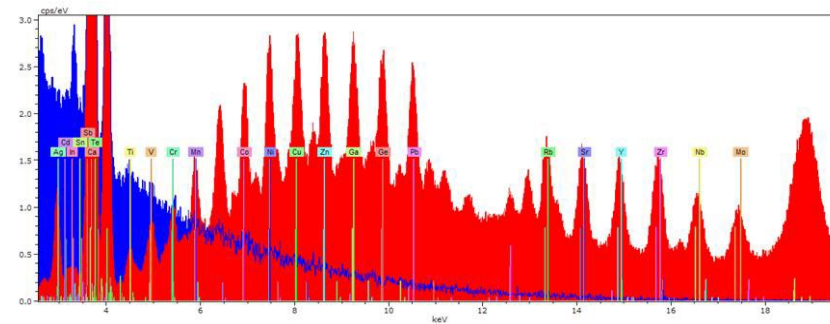
Micro-XRF M6 JETSTREAM

Butcher AR (2020) Upscaling of 2D mineralogical information to 3D volumes for geoscience applications using a multi-scale, multi-modal and multi-dimensional approach. *EMAS2019, Conference Proceedings Volume, Trondheim*, 19-23 May 2019.

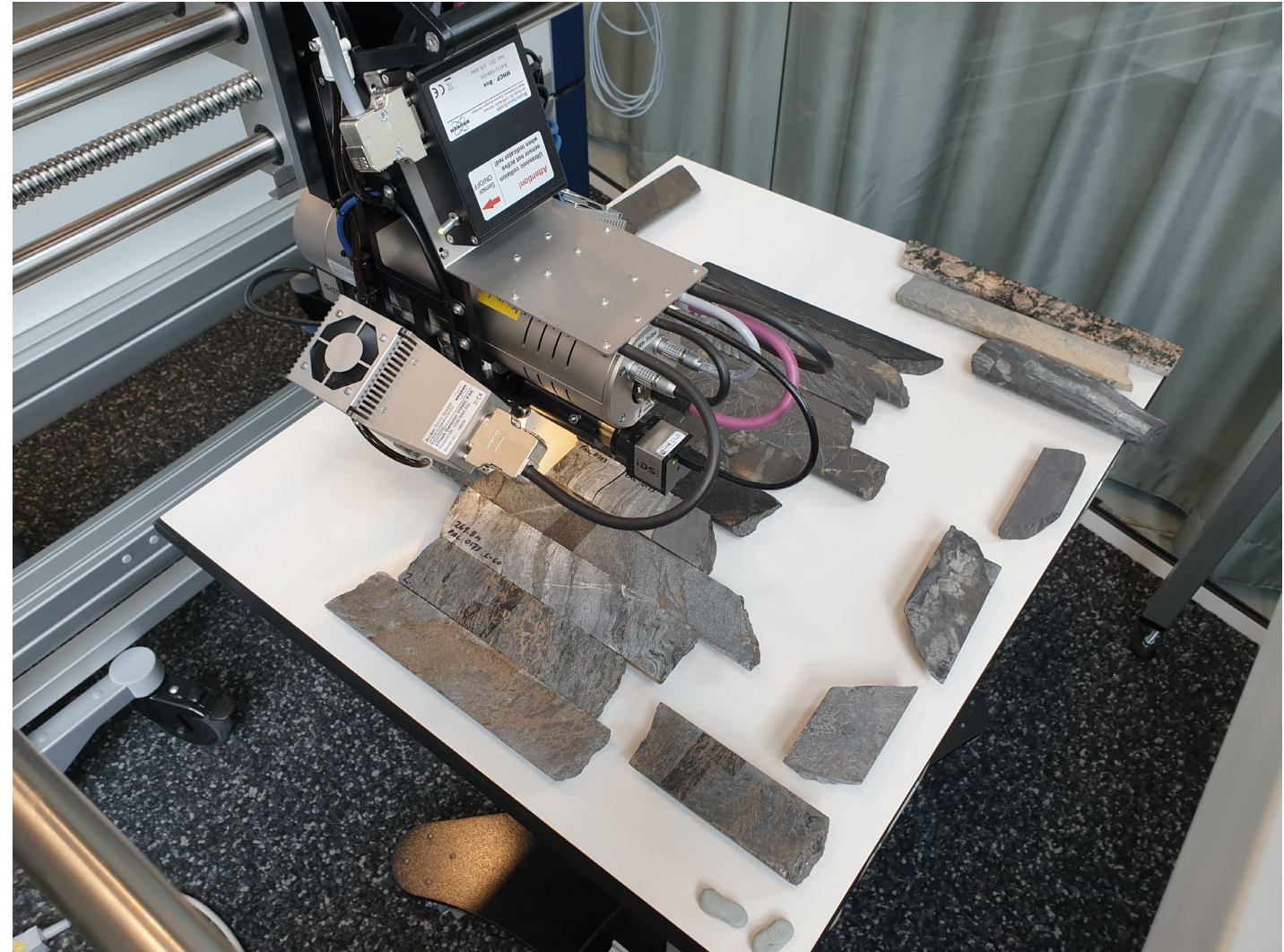
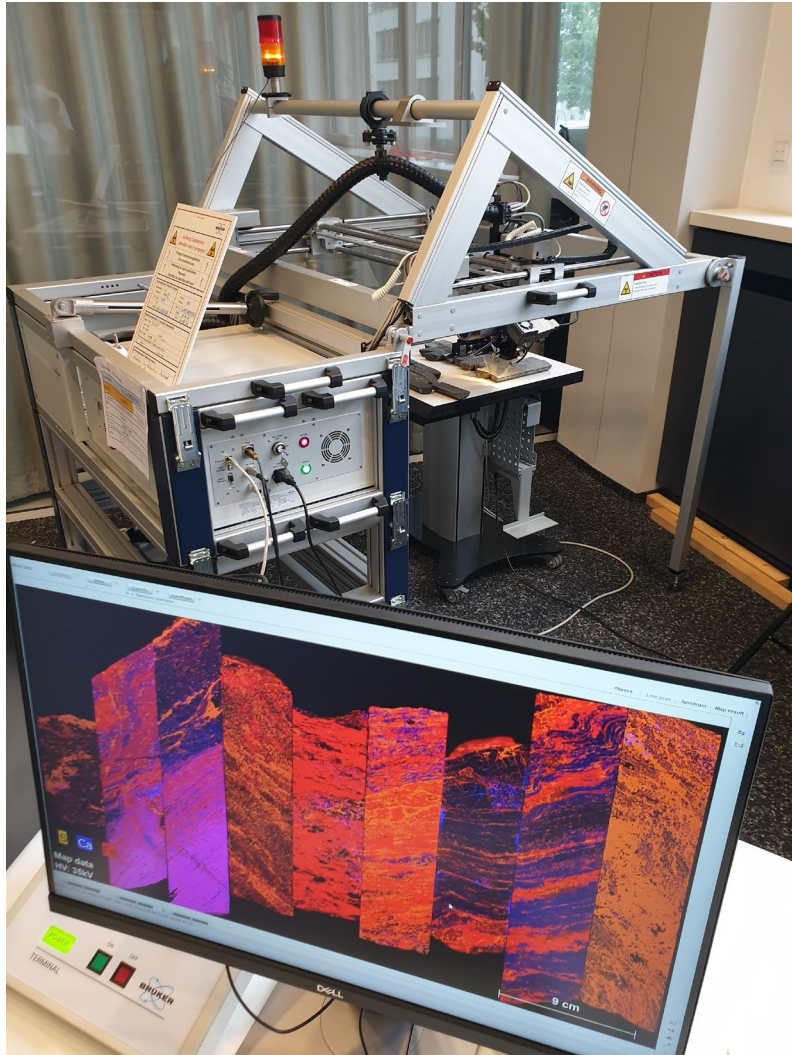
Micro-XRF Analysis: Introduction

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

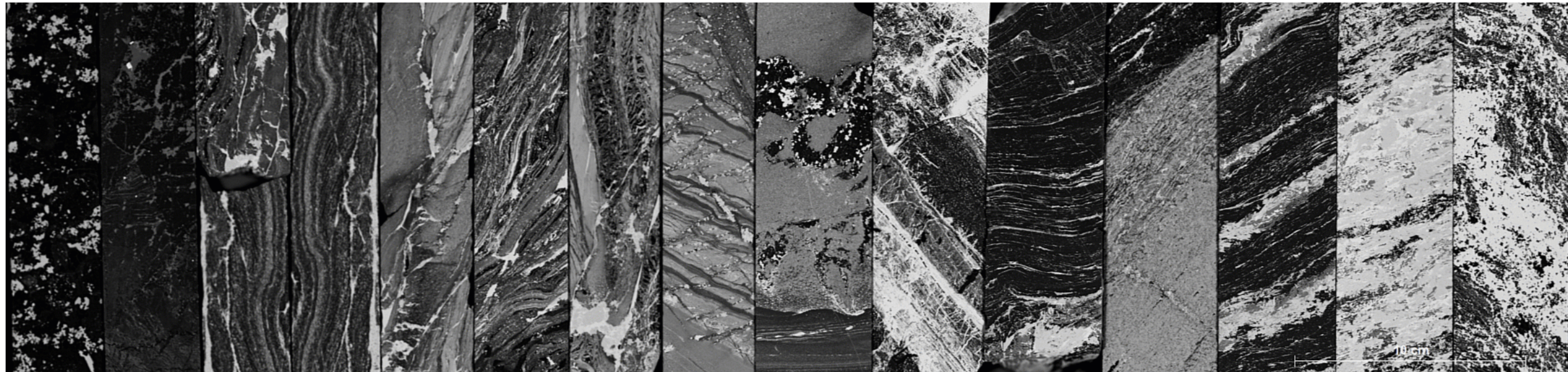


Examples: Micro-XRF M6 JETSTREAM



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

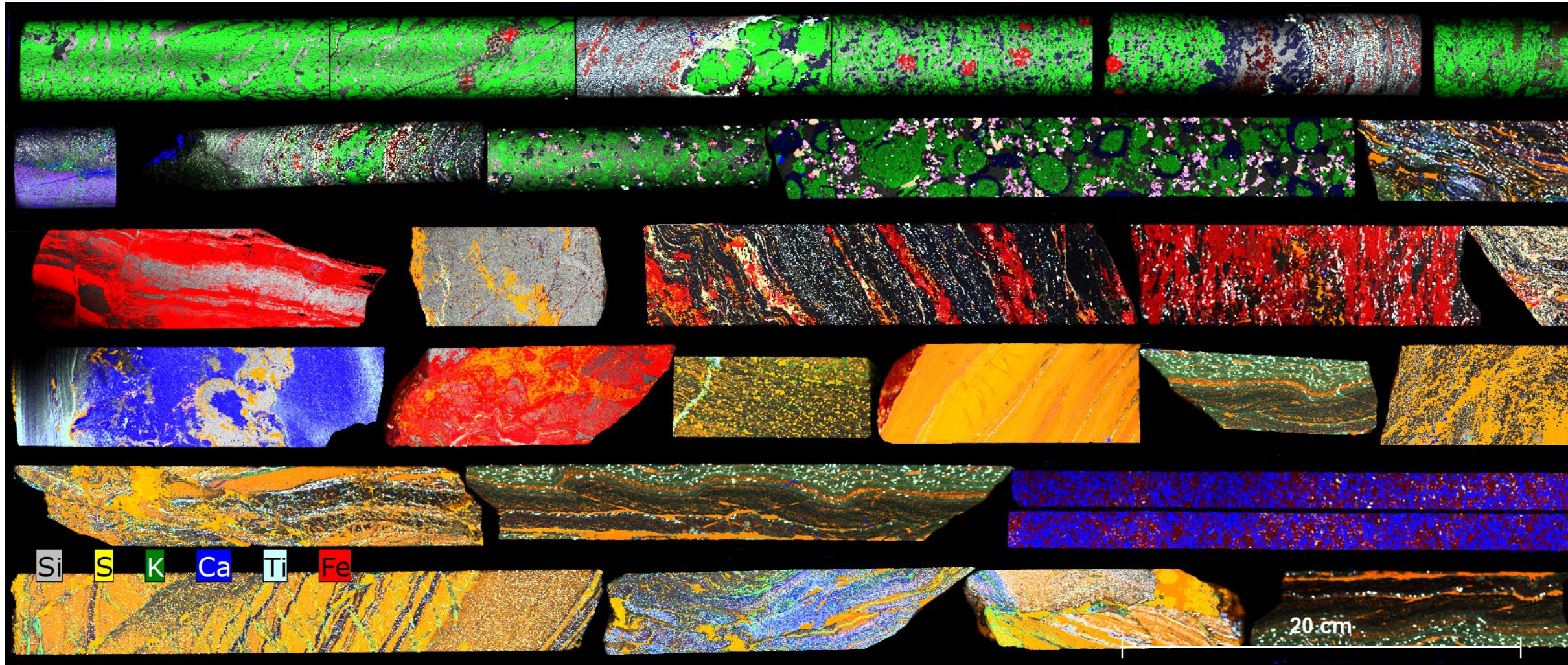


Black and White Image:
Total X-ray Intensity

Total Width 70cm

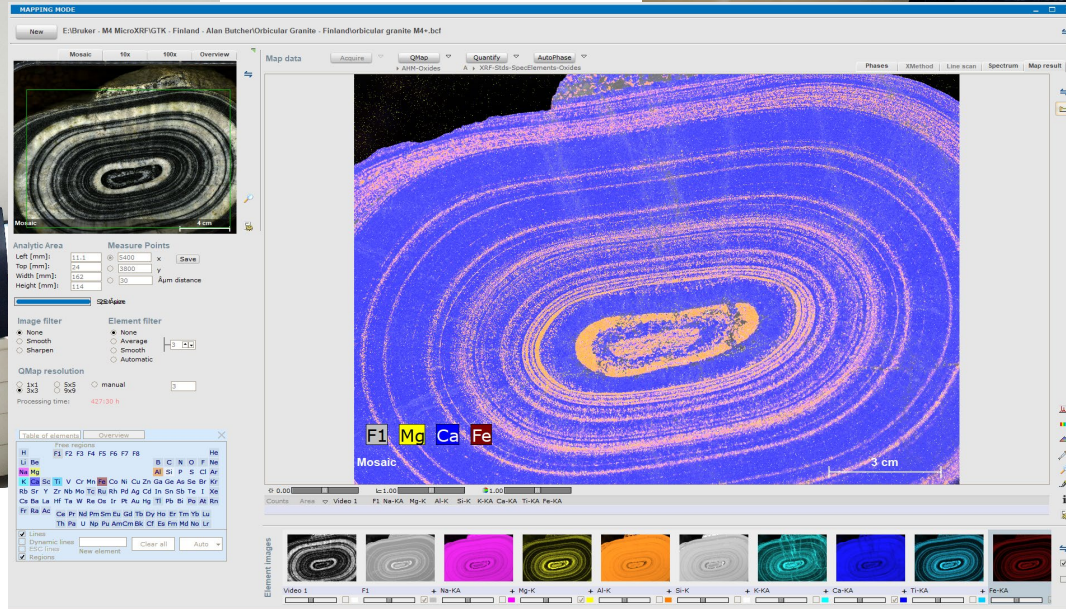
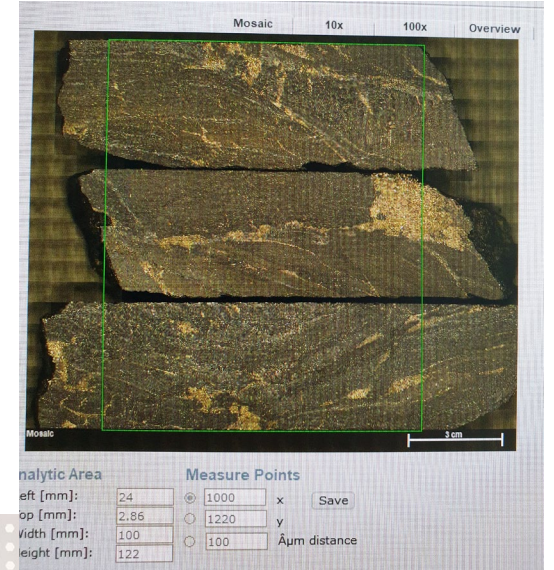
Color Image:
Multi-element Intensity Map

Examples: Micro-XRF M6 JETSTREAM: Drill Core



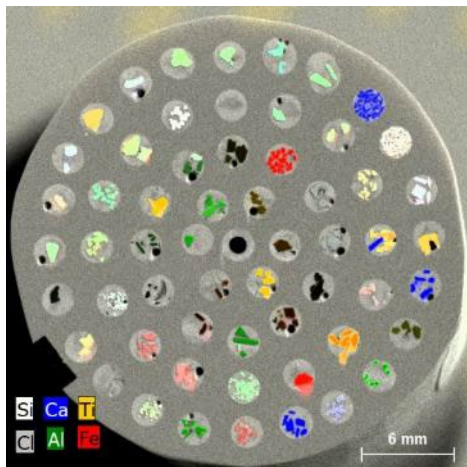
Half Core vs Cylindrical Core

Examples: Micro-XRF M4 TORNADO PLUS

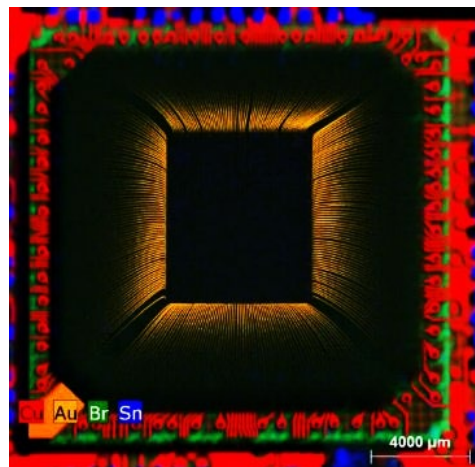


Overview: Micro-XRF as an analytical technique

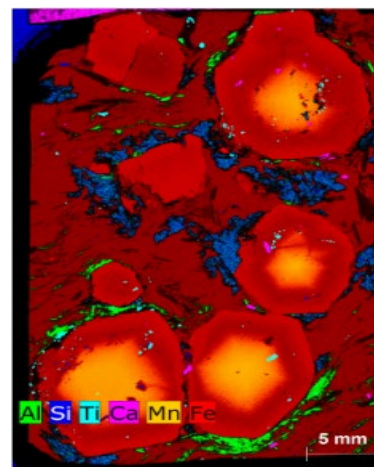
Main analytical advantages of micro-XRF



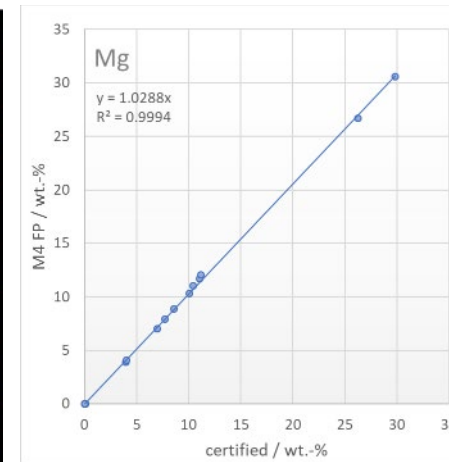
No sample preparation



Information from the depth of the sample



Trace element sensitive



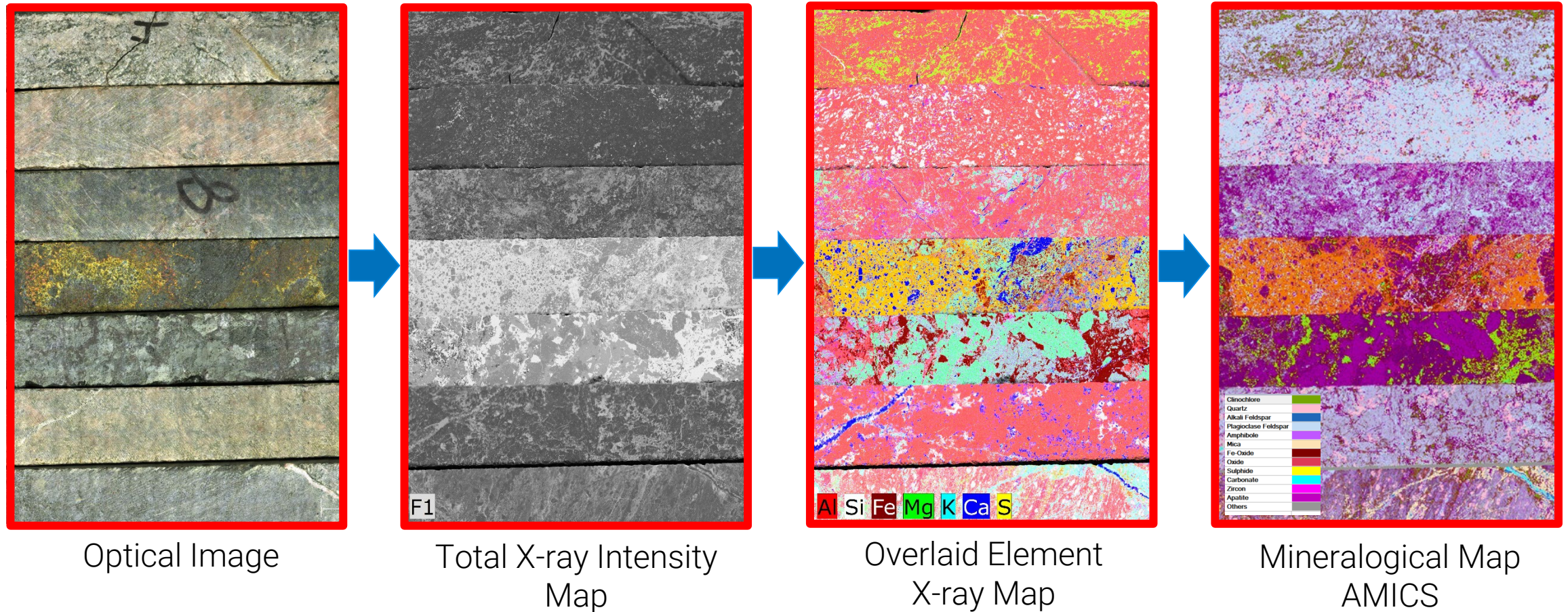
Reference samples free and standard supported quantification options



M4 TORNADO PLUS as a benchtop instrument allows faster scan of larger 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.





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**





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

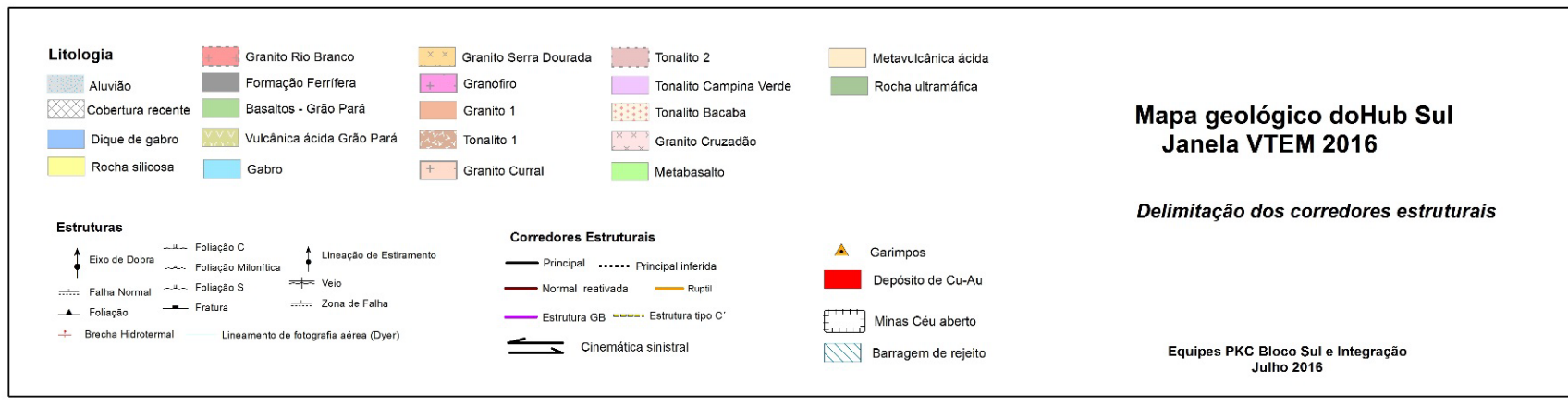
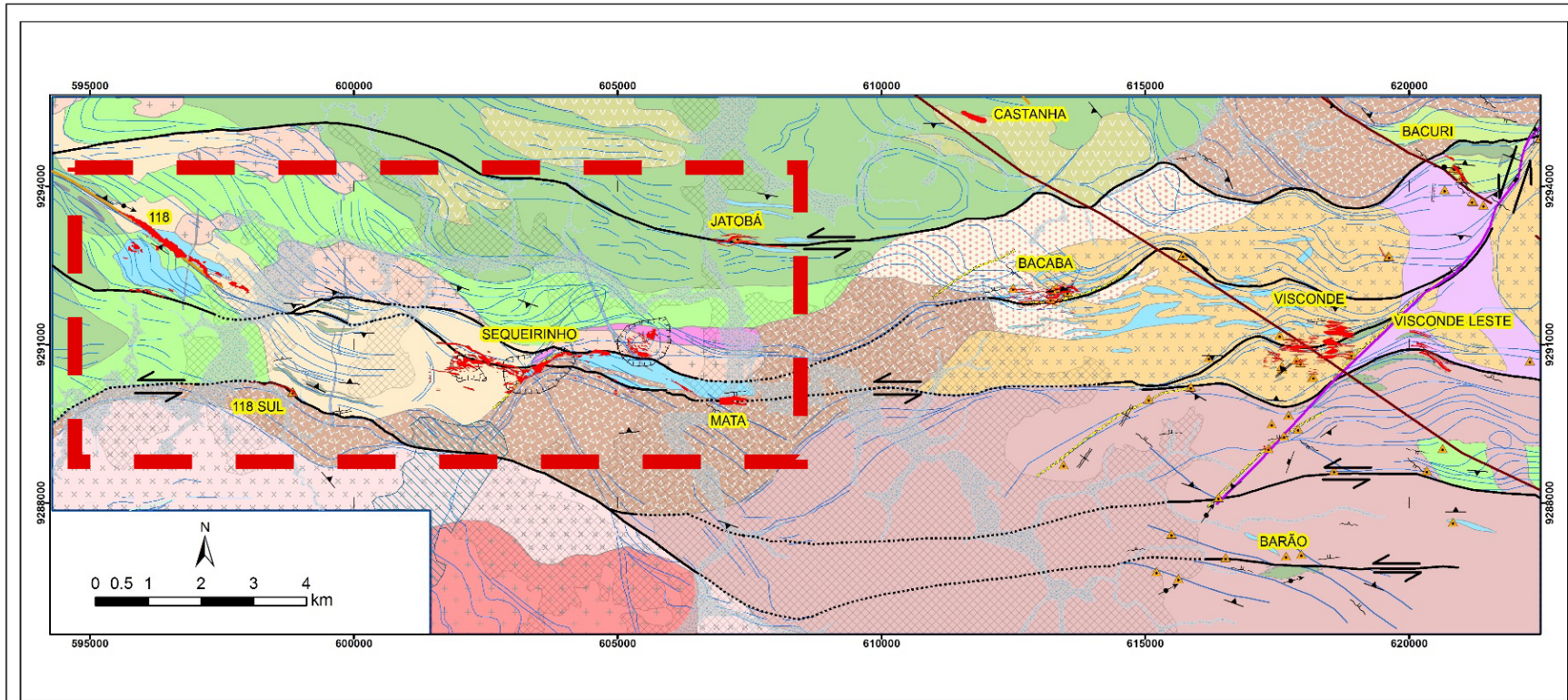
Main target: spatial distribution for the mineralogical characterization (West Sossego as a whole deposit characterization, polygon characterization etc.);

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



Sossego Complex



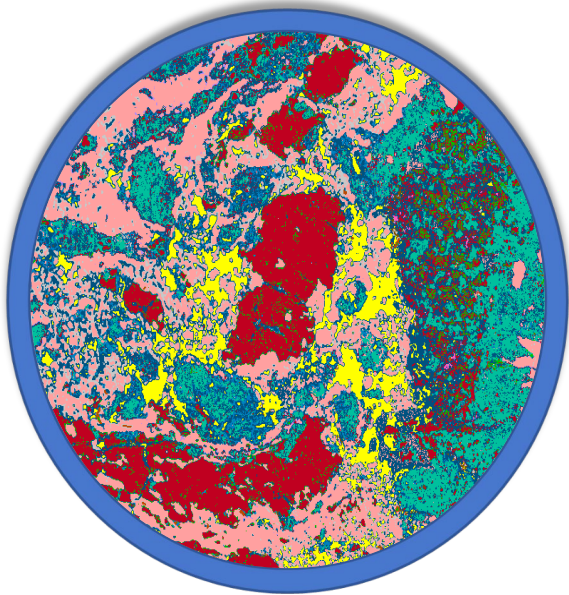


**Mapa geológico do Hub Sul
Janela VTEM 2016**

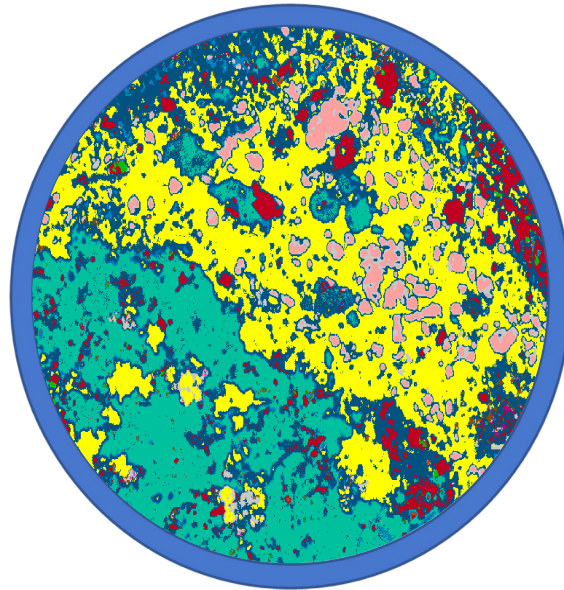
Delimitação dos corredores estruturais

Equipes PKC Bloco Sul e Integração
Julho 2016

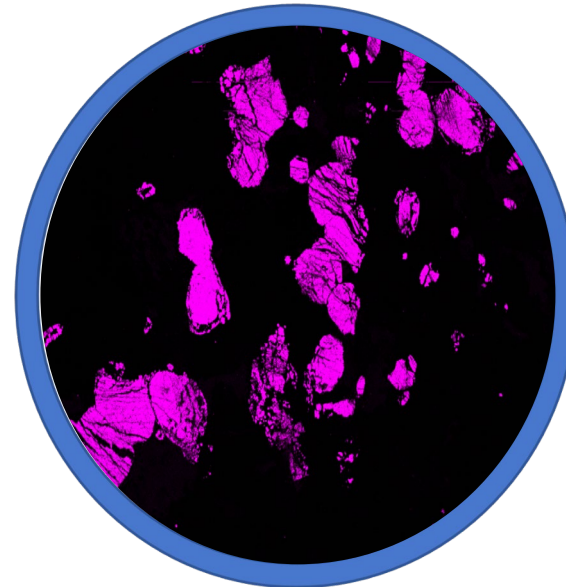
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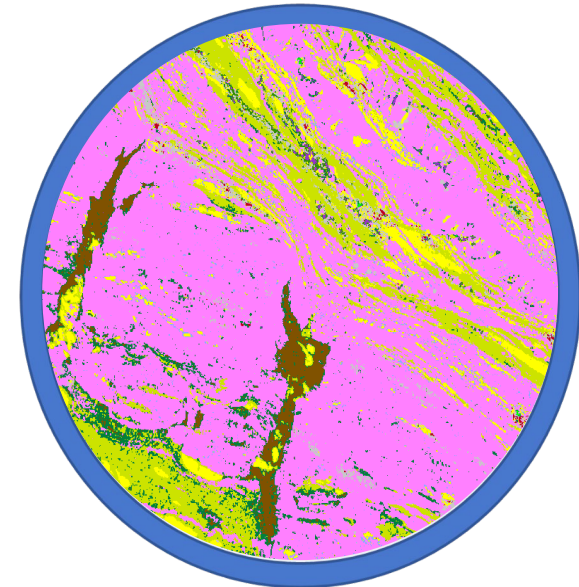
Sequeirinho



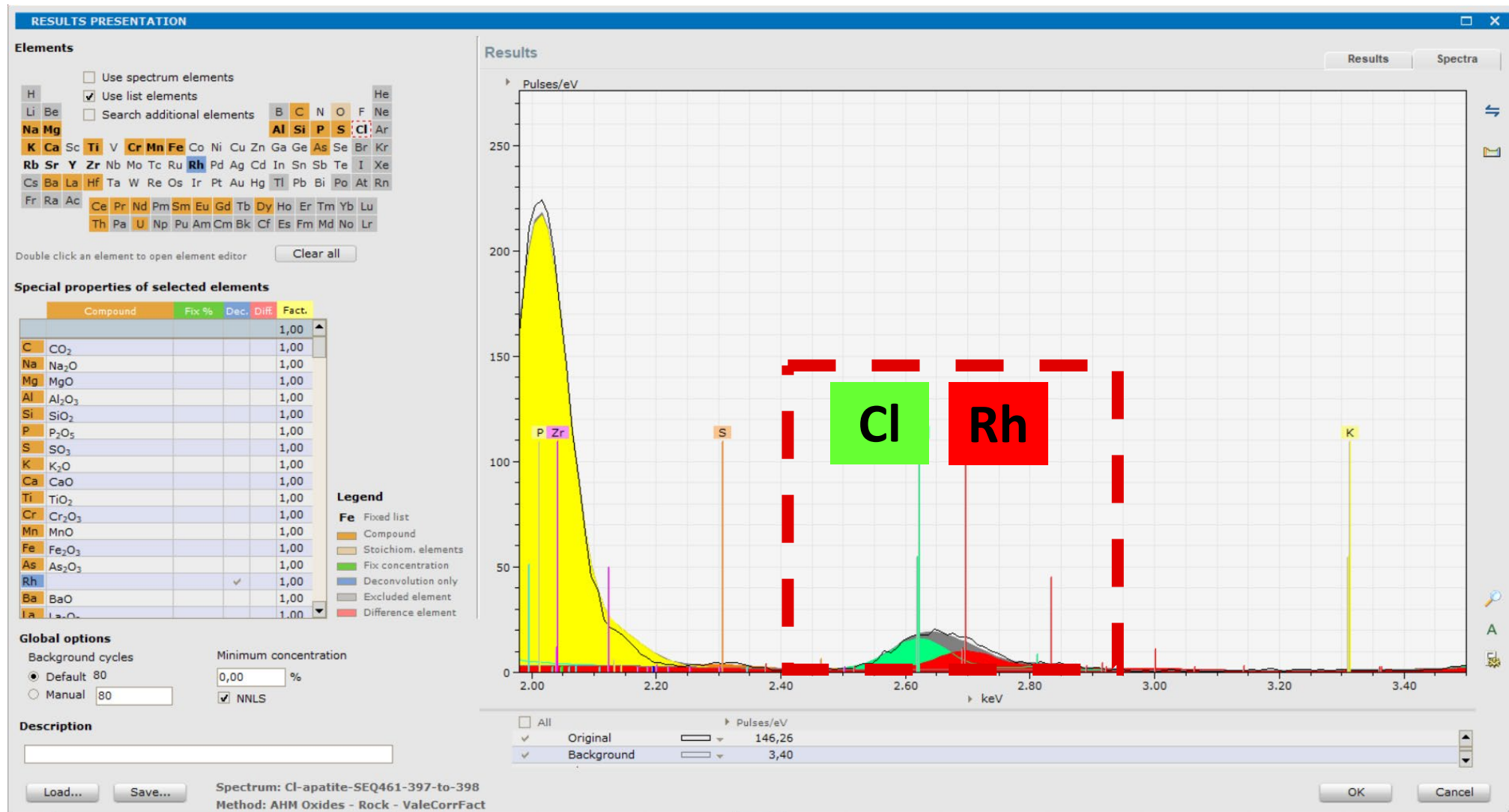
Sossego



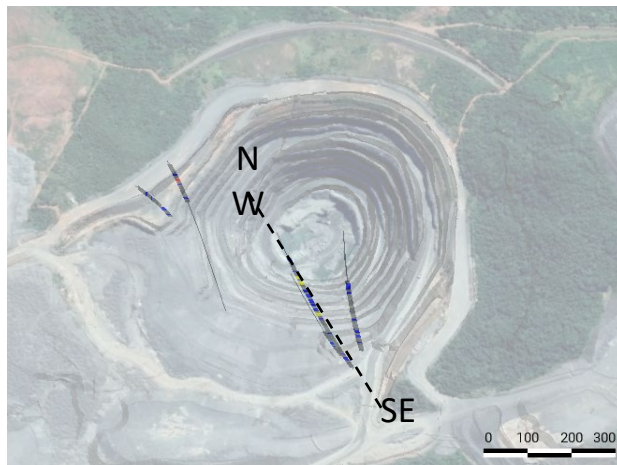
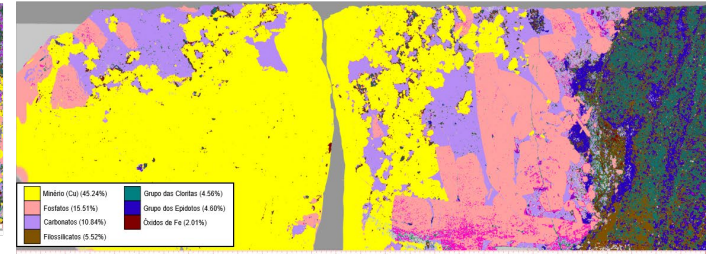
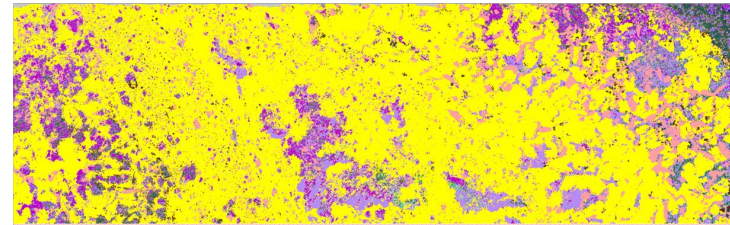
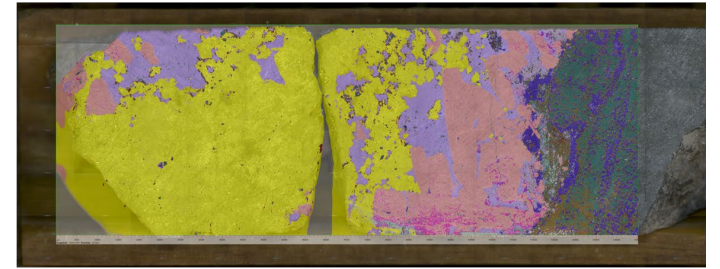
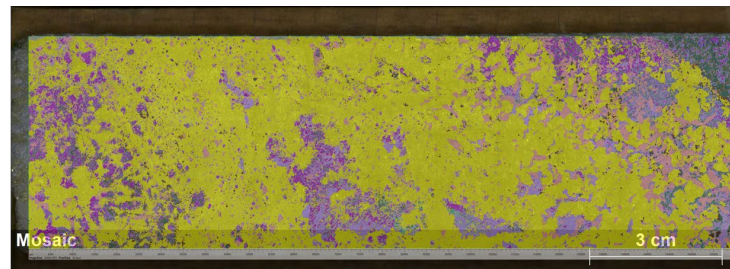
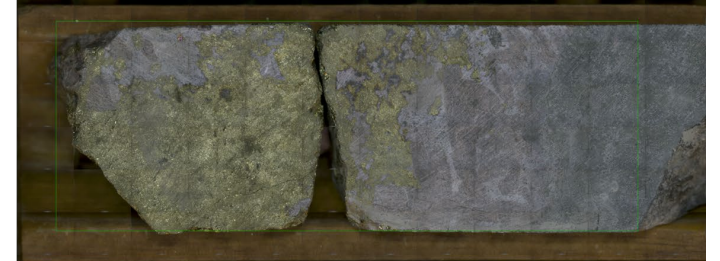
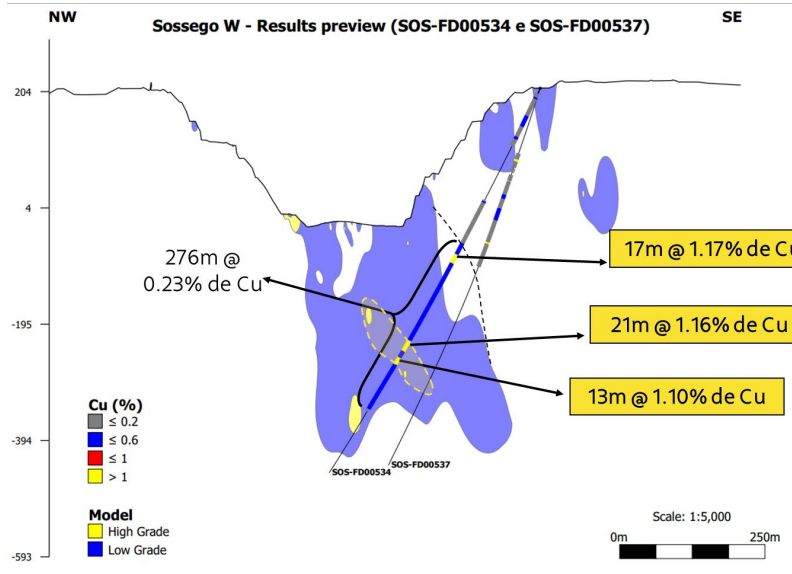
Pista



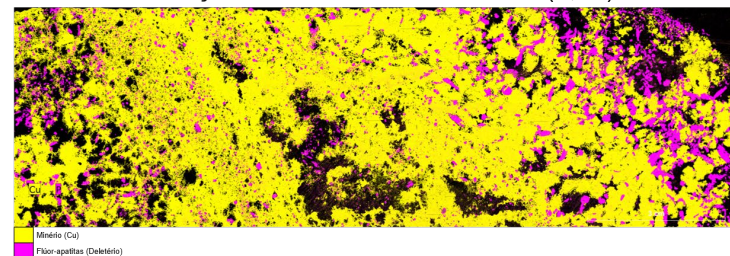
Sossego Complex Automated Mineralogy (AMICS): Penalty Elements



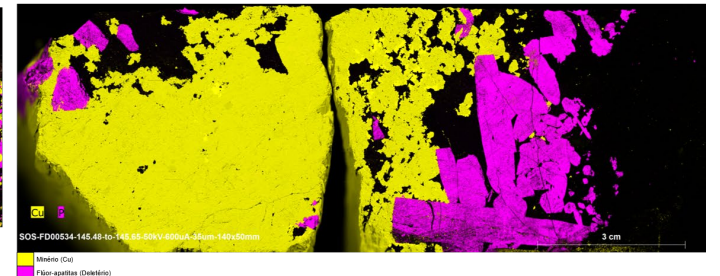
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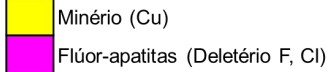
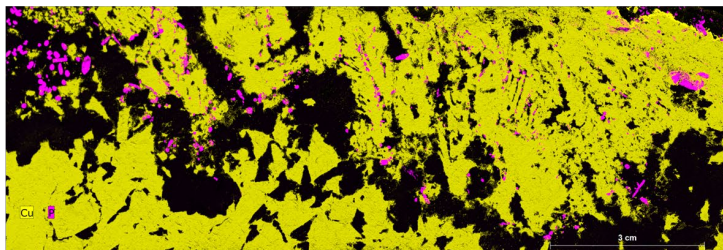
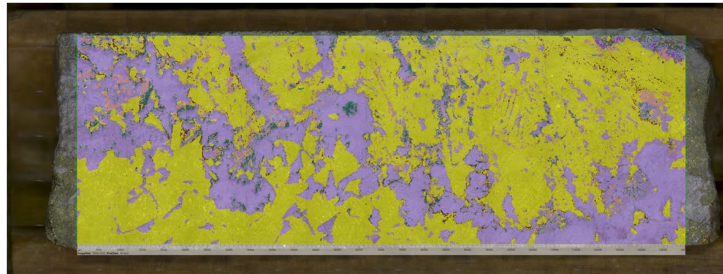
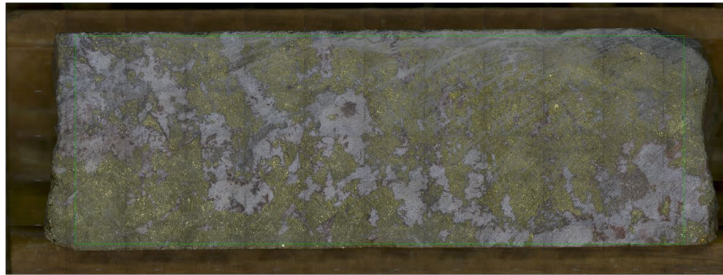
Relação textural: Cobre vs Fosfatos (F, Cl)



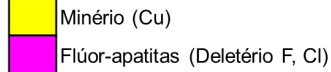
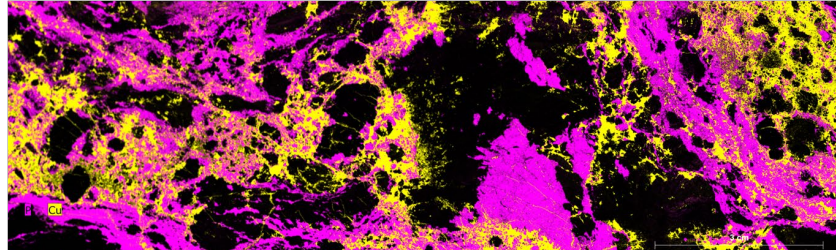
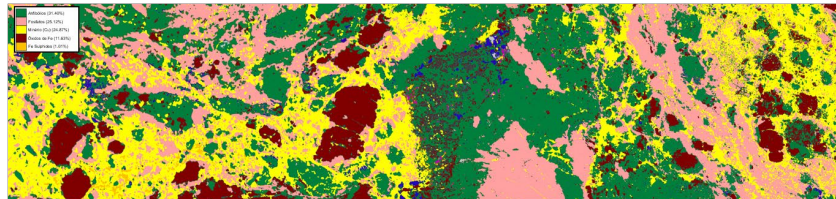
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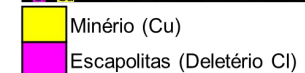
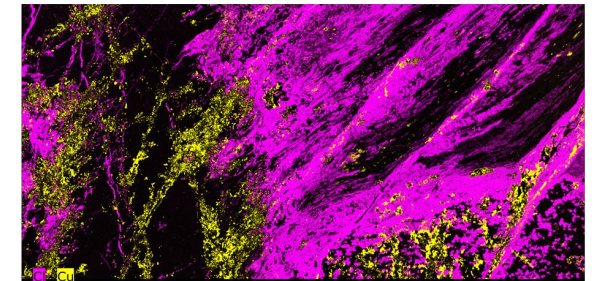
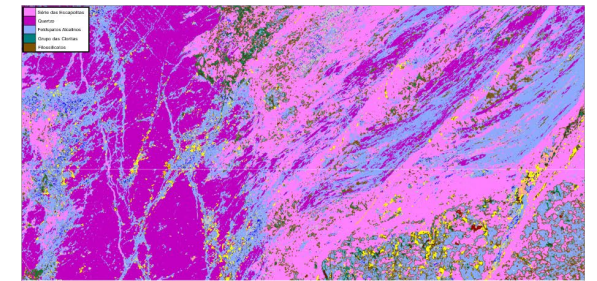
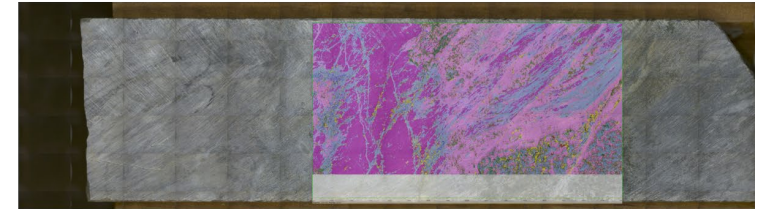
Sossego Complex Automated Mineralogy (AMICS): Penalty Elements



SOSSEGO W



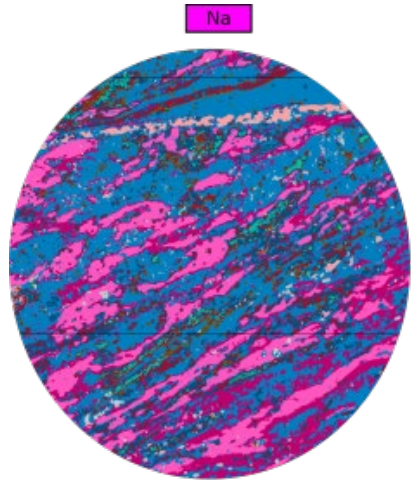
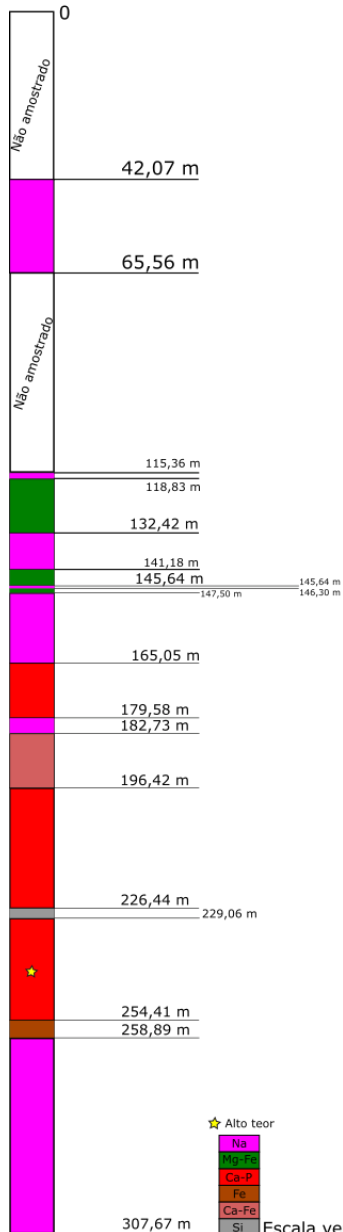
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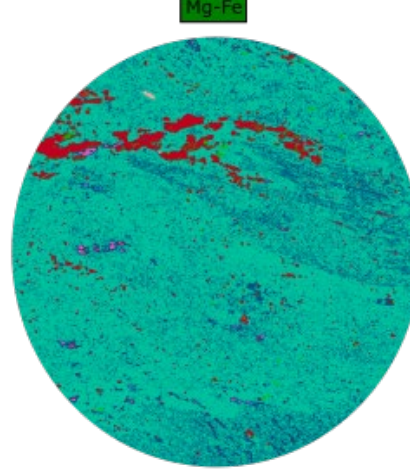
PISTA

Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

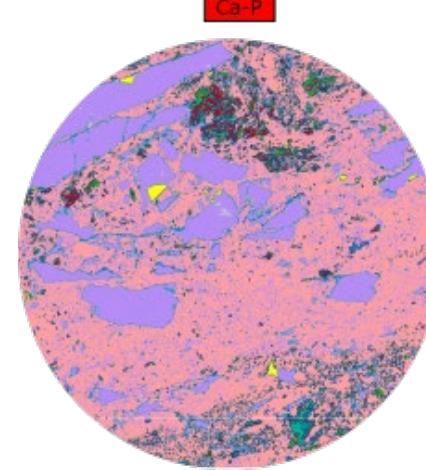
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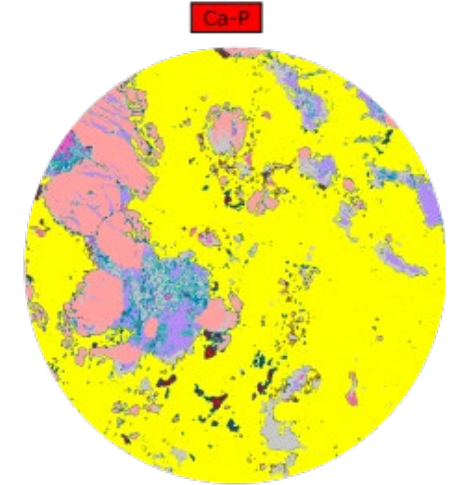
Scapolite Series (42,05%)
Alkali Feldspar (12,25%)



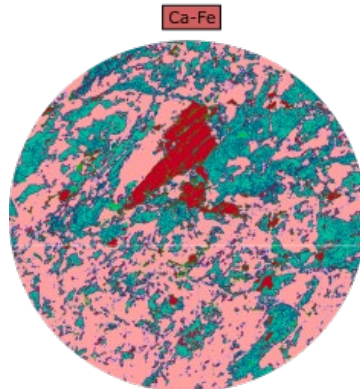
Chlorite Group (73,87%)
Epidote Group (18,70%)



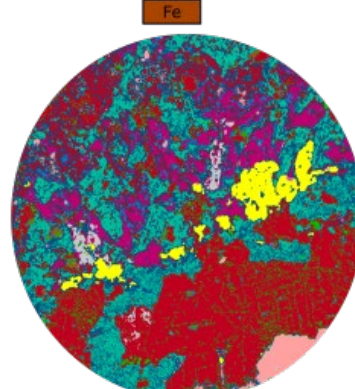
Phosphates (55,45%)
Carbonates (19,94%)
Epidote Group (14,48%)
Sulphides (0,13%)



Phosphates (8,43%)
Sulphides (59,73%)



Phosphates (46,30%)
Epidote Group (18,97%)
Amphiboles (17,75%)
Fe Oxides (10,20%)

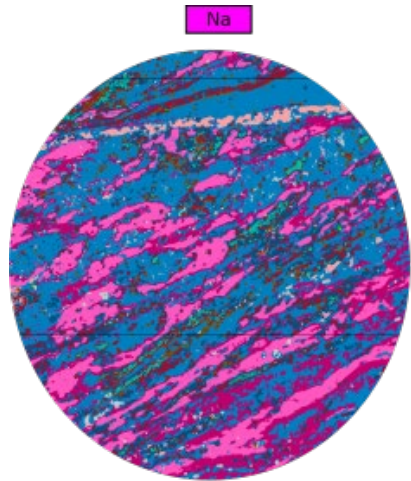
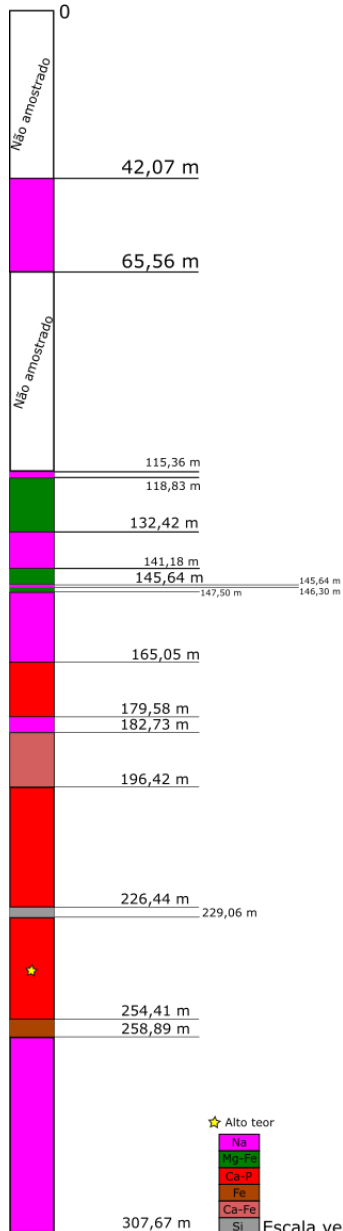


Fe oxides (25,06%)
Amphiboles (14,16%)
Chlorite Group (5,03%)

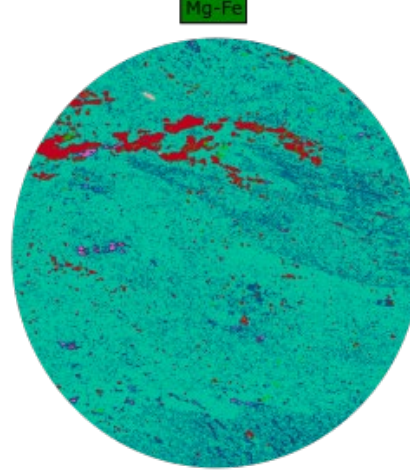
★ Alto teor
Na
Ca-P
Fe
Ca-Fe
Si
Escala vertical: 1:1

Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

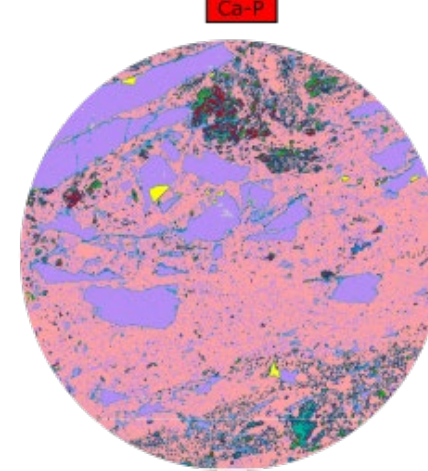
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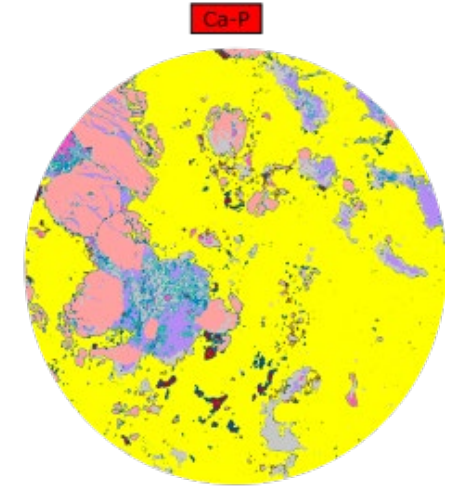
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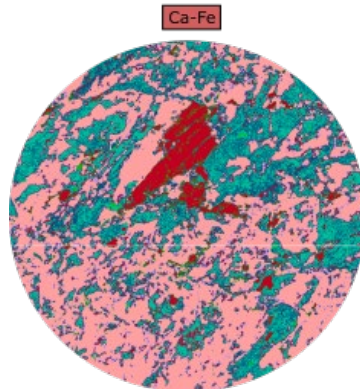
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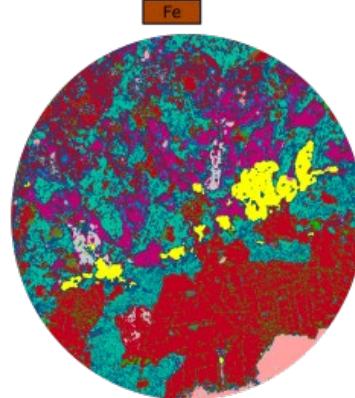
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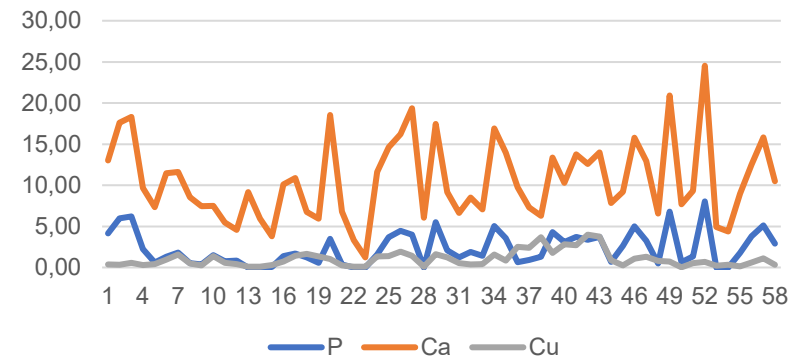


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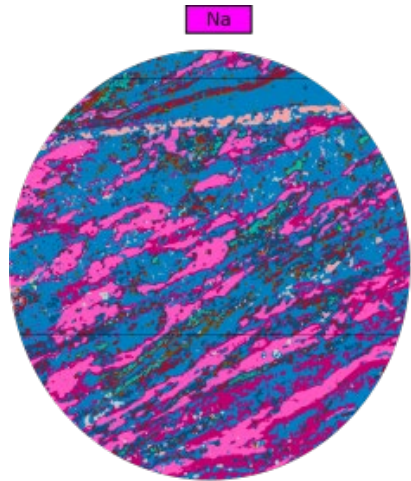
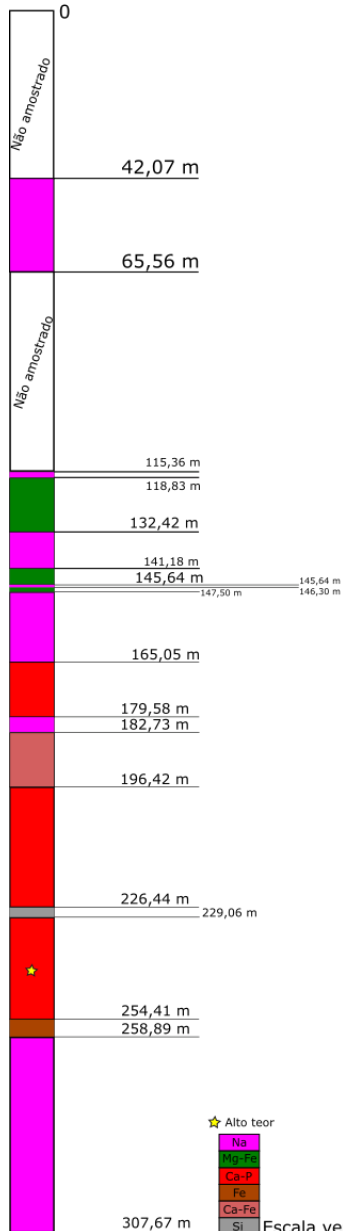
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P x Ca x Cu

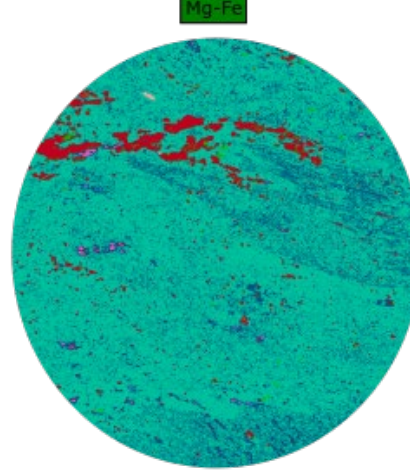


Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

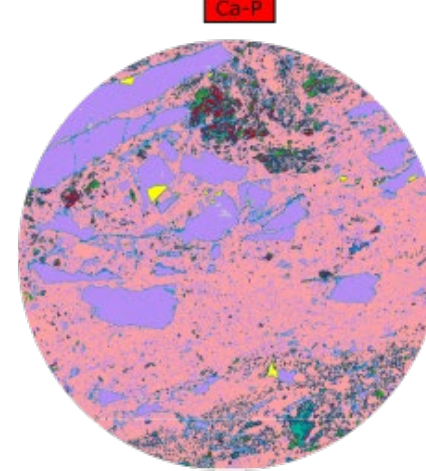
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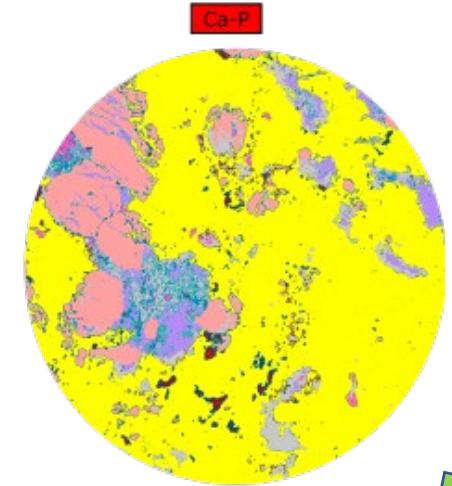
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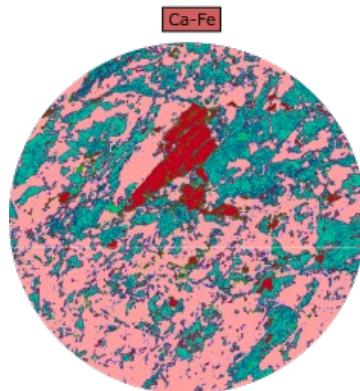
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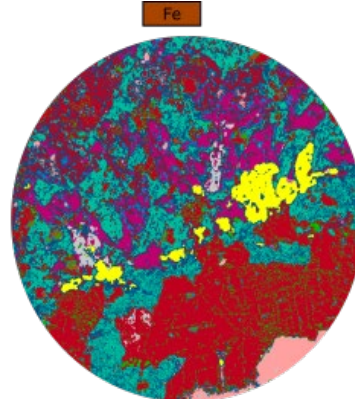
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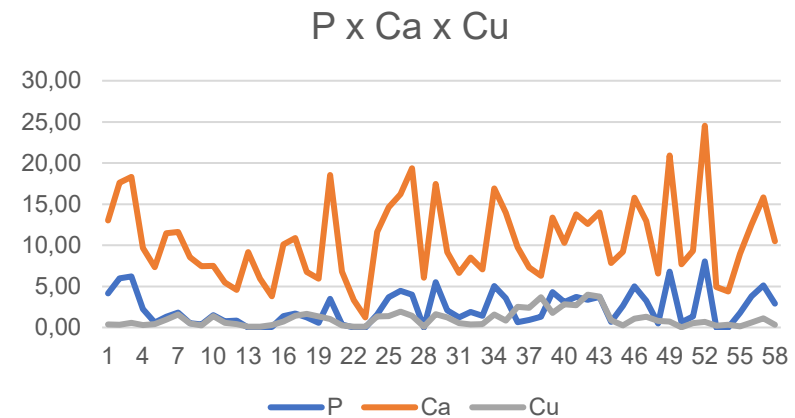


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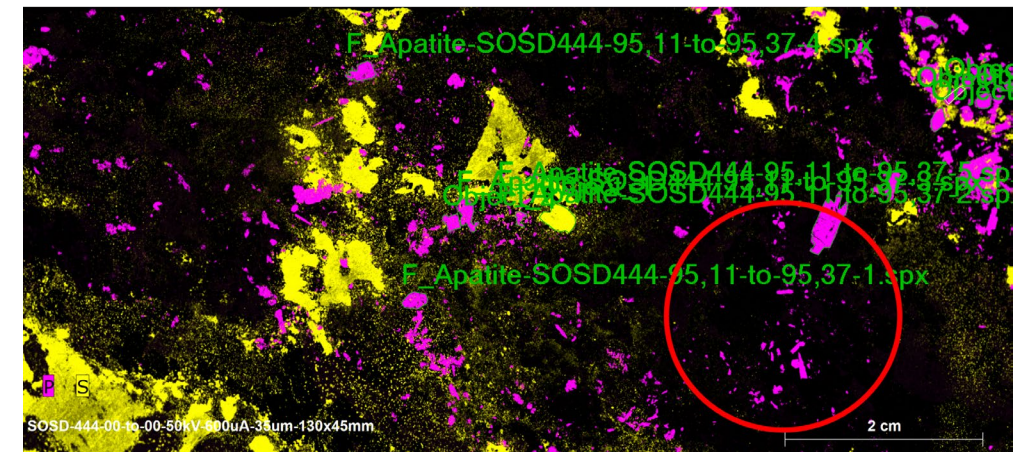
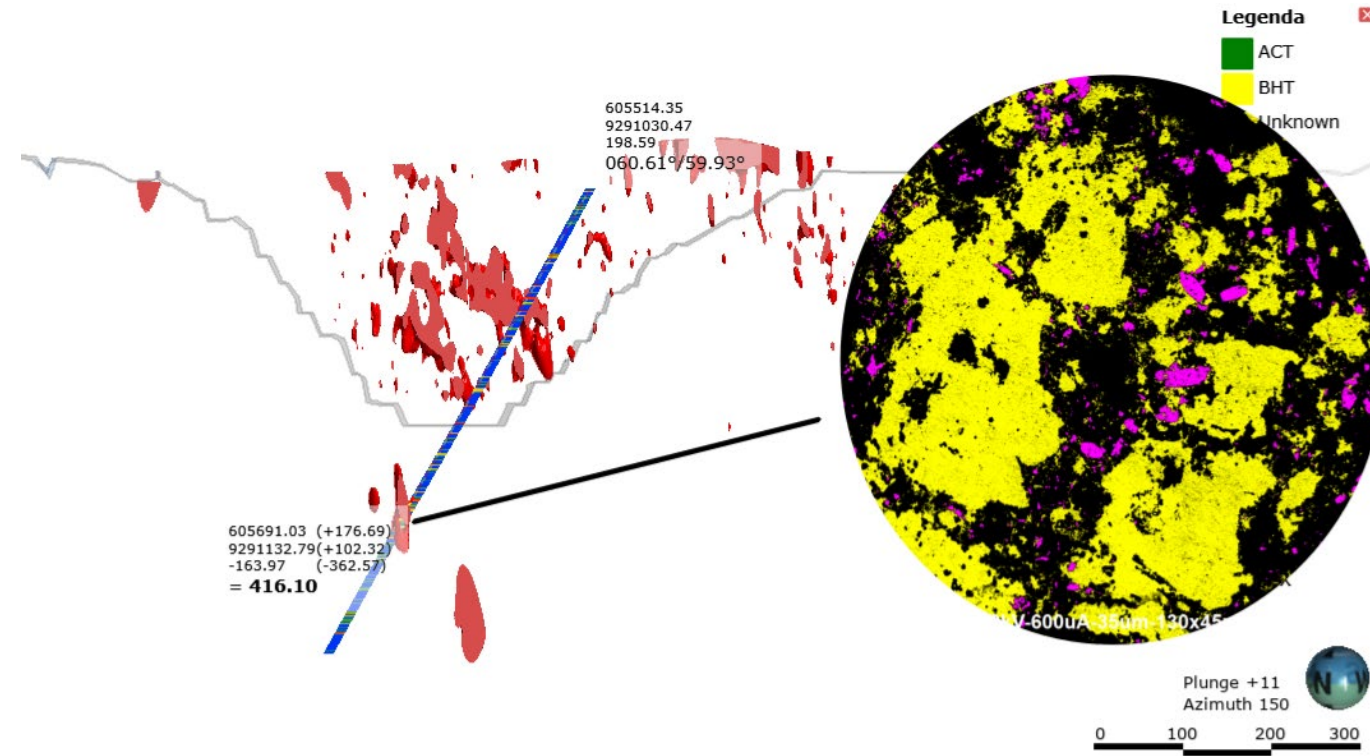


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Chlorite Group (5,03%)

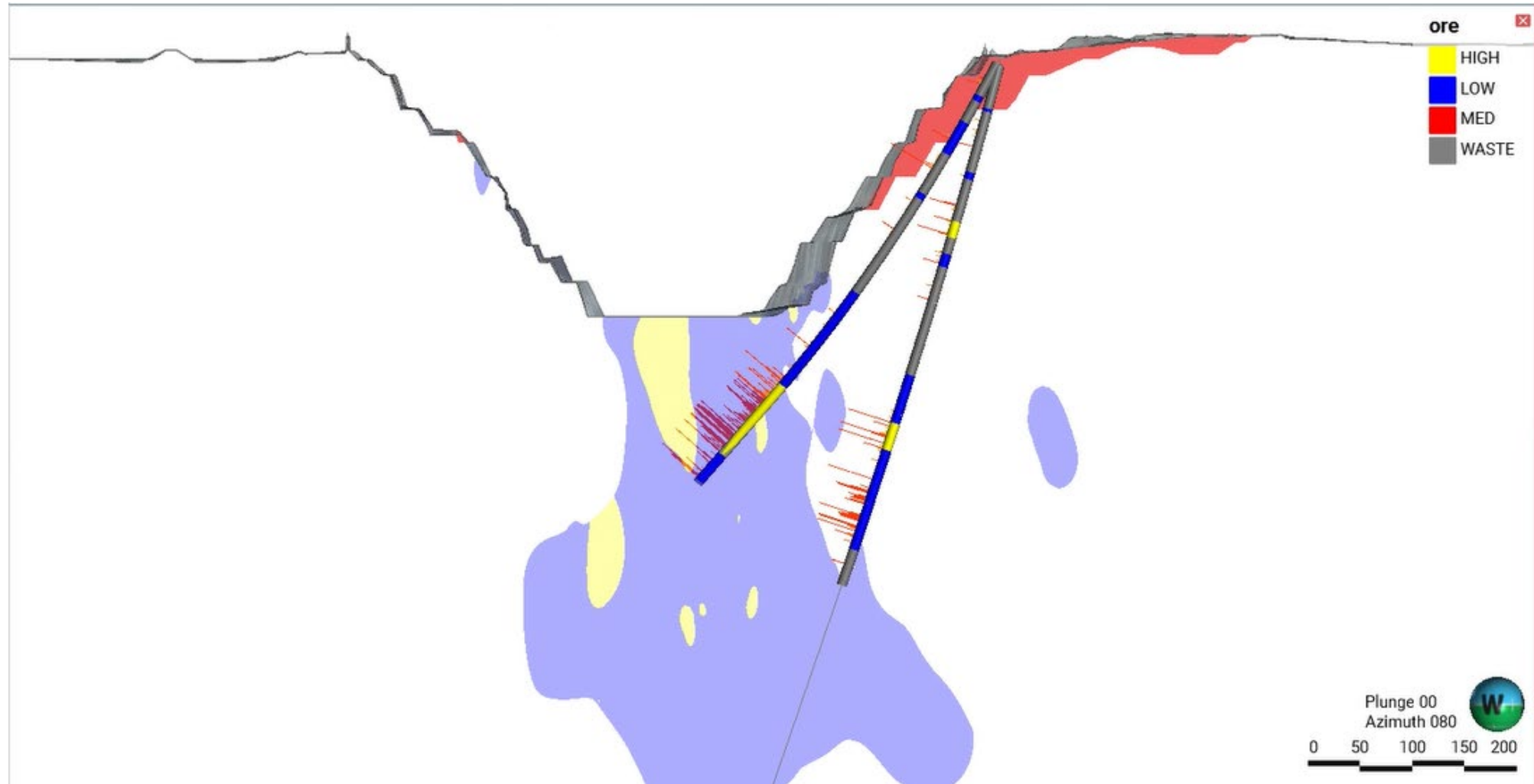
IOCG PATHFINDERS



Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders



Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders



Classificação Mineralógica

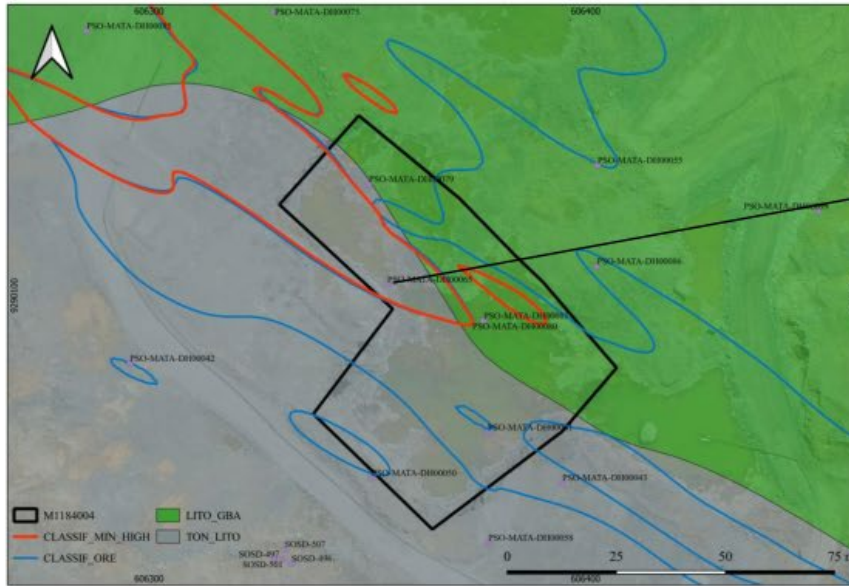
Epidoto 24.21%
Sulfetos 16.36%
Anfibólio 11.20%
Fosfatos 11.20%

M1_184_004
Polígono

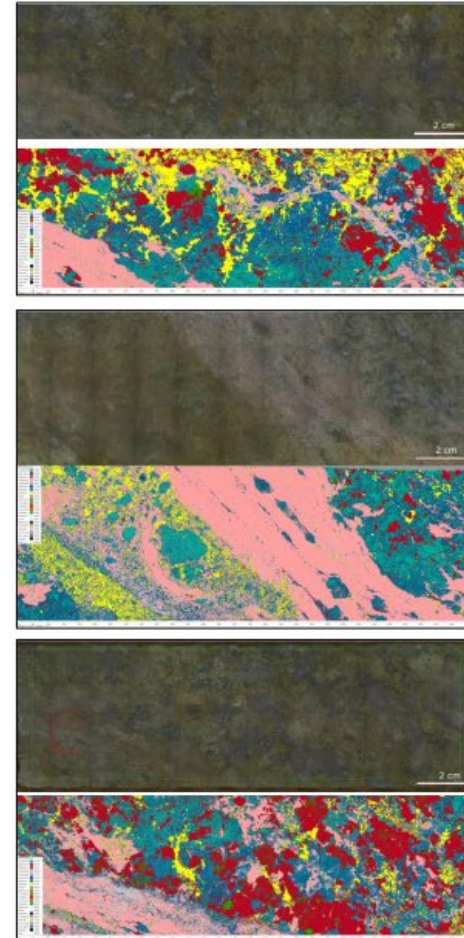
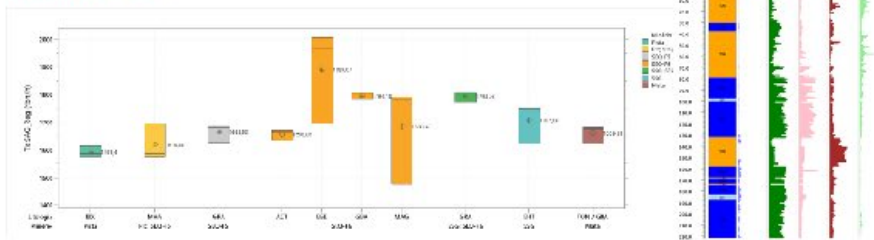
71872 Kt
Massa Prevista para
compor o blend de
alimentação da
britagem.

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
(anfیبólios 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



- 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
Polígono

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

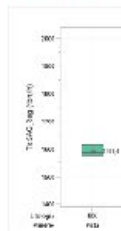
0,875 Cu%
Teor Liberação

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

Classificação Litológica



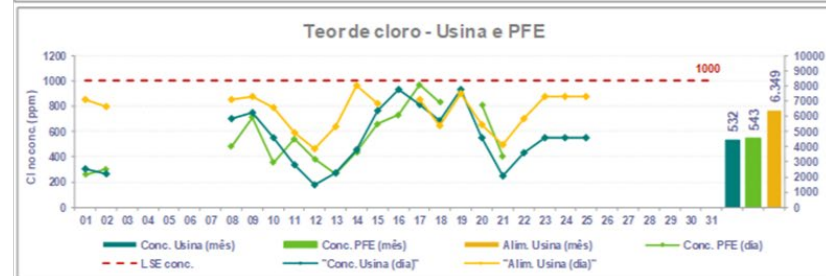
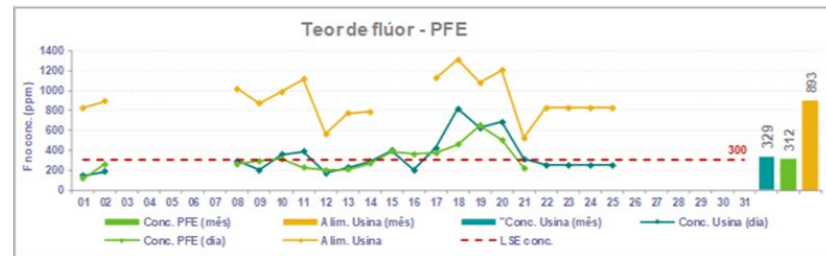
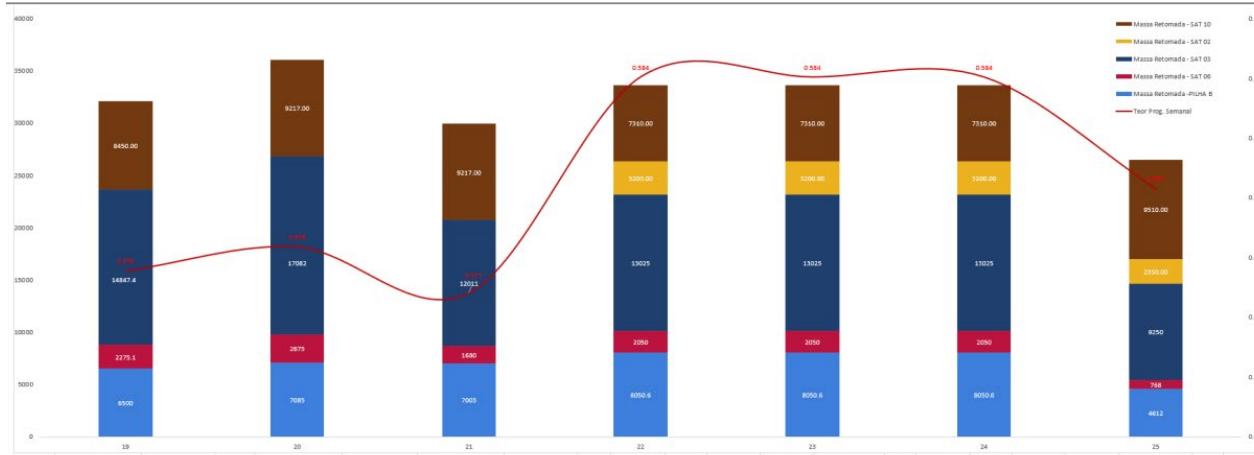
Boxplot da Taxa / Litologia do M1



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



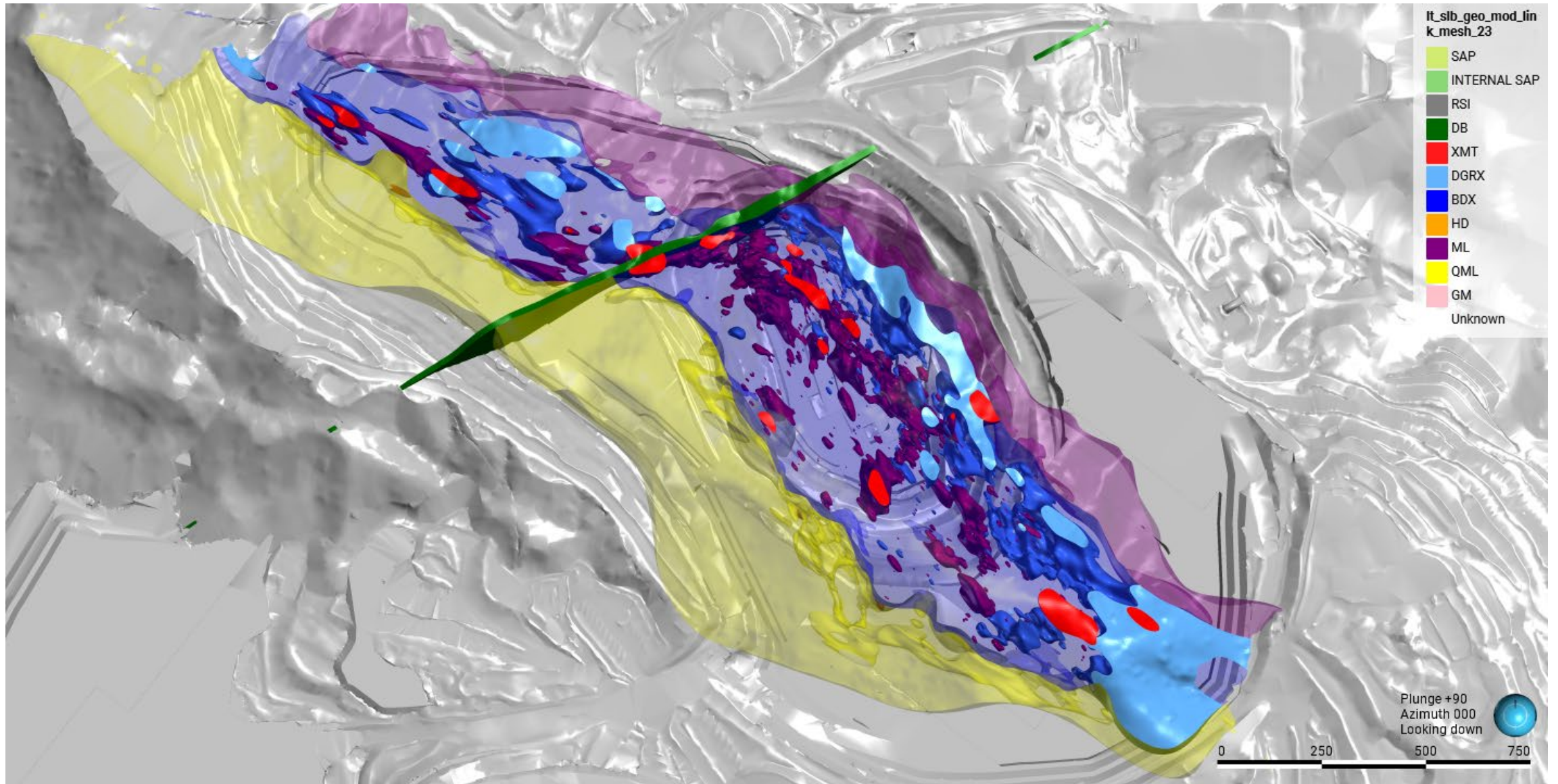
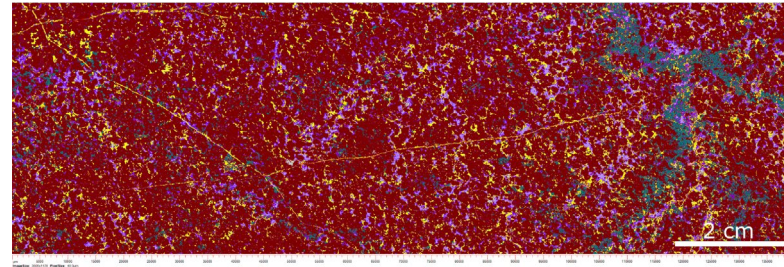
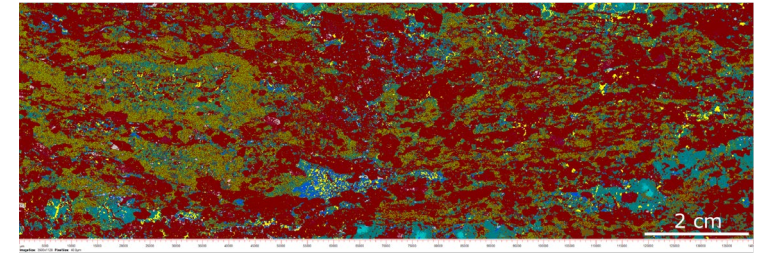


Image courtesy of Valter Oliveira (Vale Base Metals)

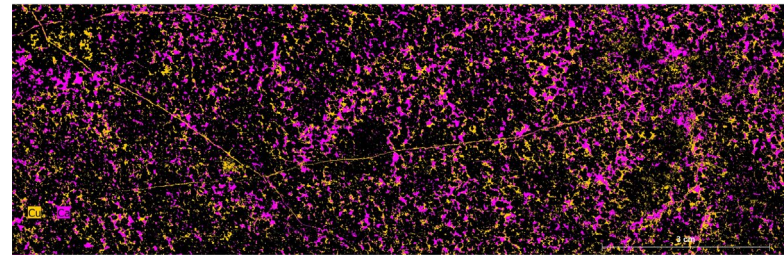
Salobo Automated Mineralogy (AMICS): Magnetic Schists Case



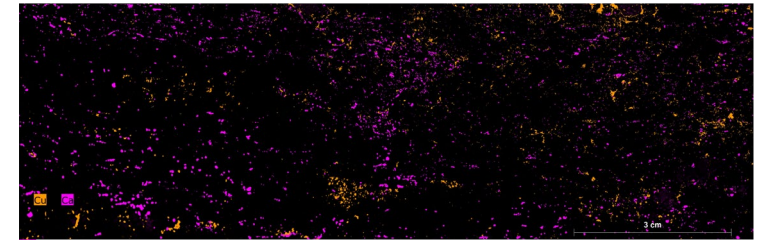
Apatitas (F, Cl) (0.19%)	Ferro-pirossmalita (Cl) (0.90%)	Olivinas (Fayalita) (5.11%)	Turmalina (0.064%)
Sulfetos de Cu (7.50%)	Carbonatos (calcita) (2.23%)	Magnetita (62.50%)	Oxidos de U (Uraninita) (6.71%)
Pirofilitas/Talco (0.00%)	Clinocloro (4.97%)	Granadas (Almandina) (2.89%)	Fluorita (F) (5.83%)



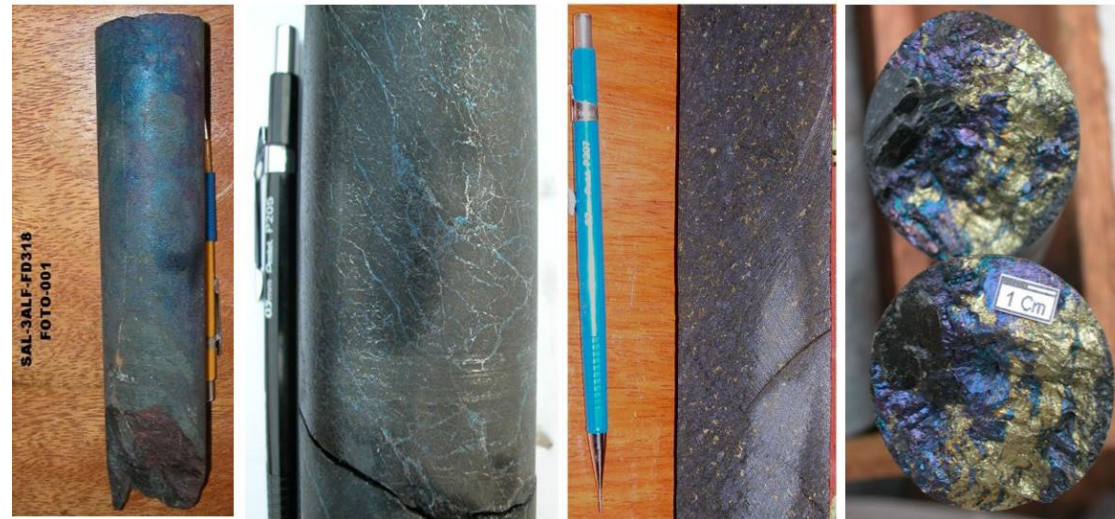
Apatitas (F, Cl) (0.20%)	Ferro-pirossmalita (Cl) (0.97%)	Magnetita (60.75%)
Sulfetos de Cu (1.43%)	Clinocloro (16.09%)	Olivinas (Fayalita) (13.95%)
Granadas (Almandina) (1.74%)	Oxidos de U (Uraninita) (0.29%)	Turmalina (0.29%)
Turmalina (0.29%)	Fluorita (F) (0.002%)	



Cobre
Fluoritas (F)



Cobre
Fluoritas (F)



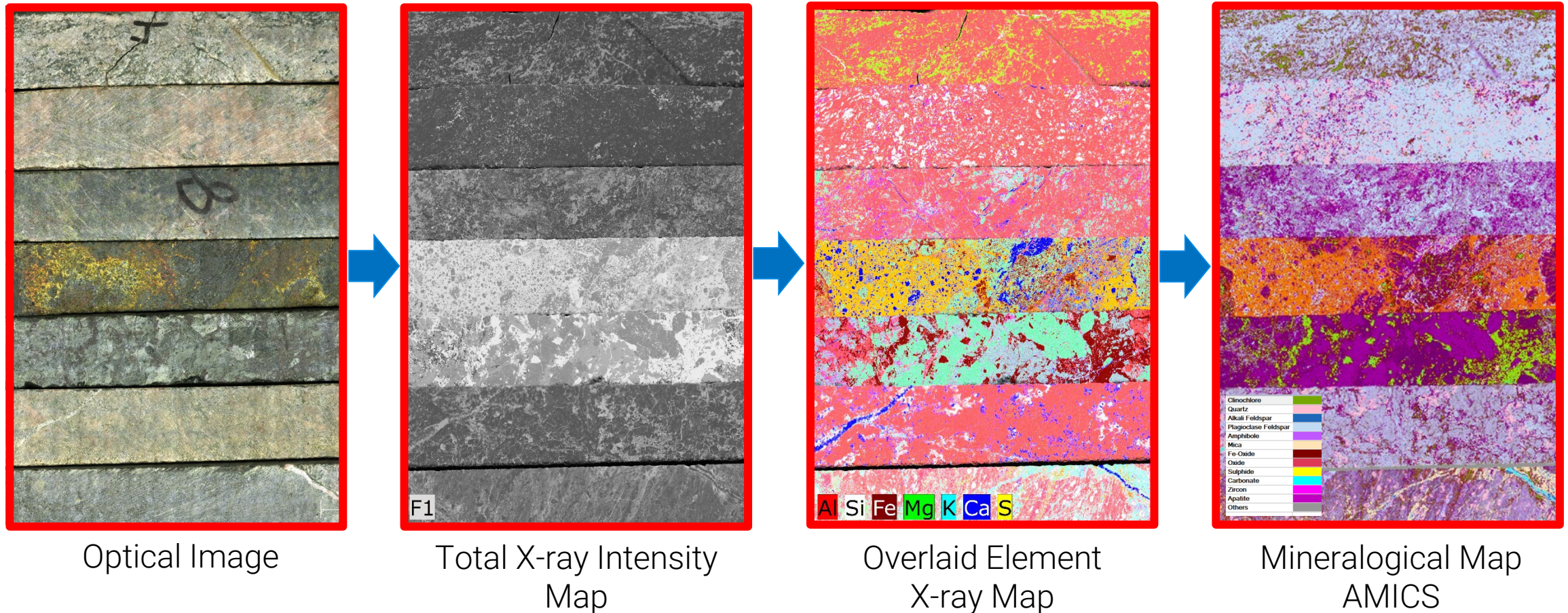


WEBINAR: GREENFIELD AND BROWNFIELD MINING EXPLORATION PROJECTS

Micro-XRF workflow examples

Analysis of Drill Core Samples: Workflow

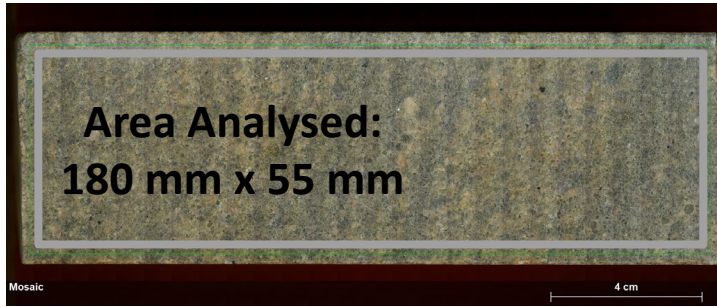
Example of the Samples (7x Drill Cores) as analyzed in the microXRF M4 TORNADO.



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.

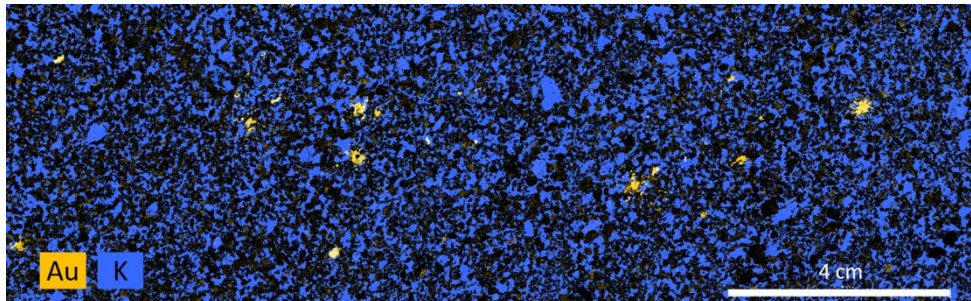
Optical



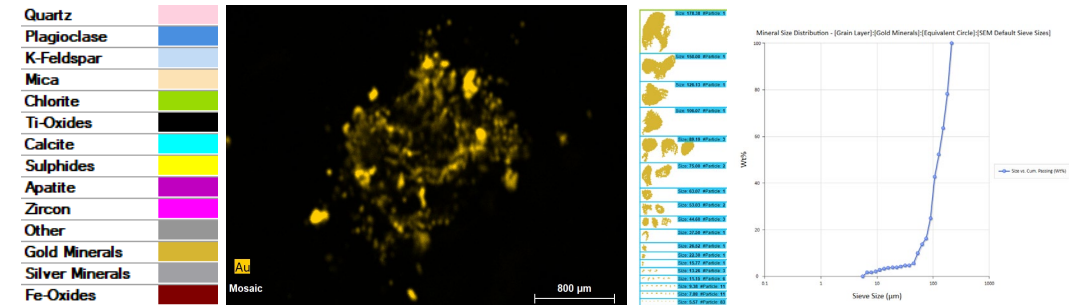
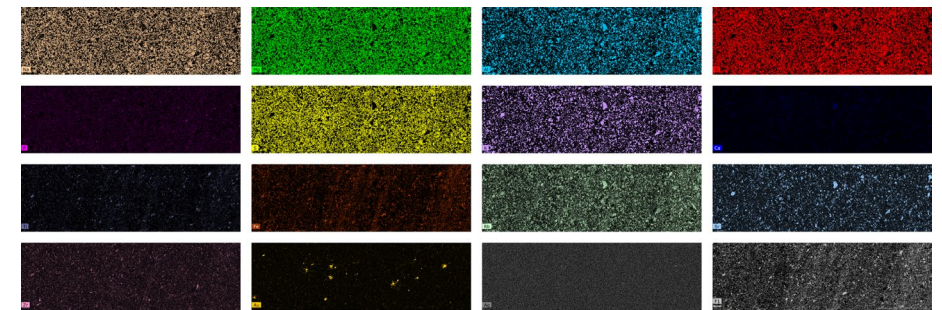
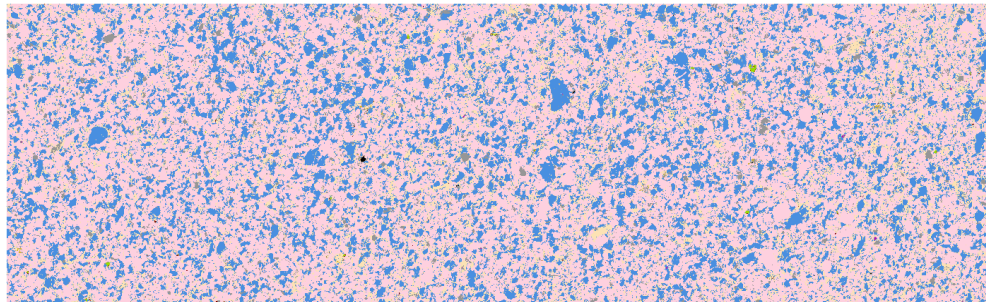
Micro-XRF images:

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

Elemental



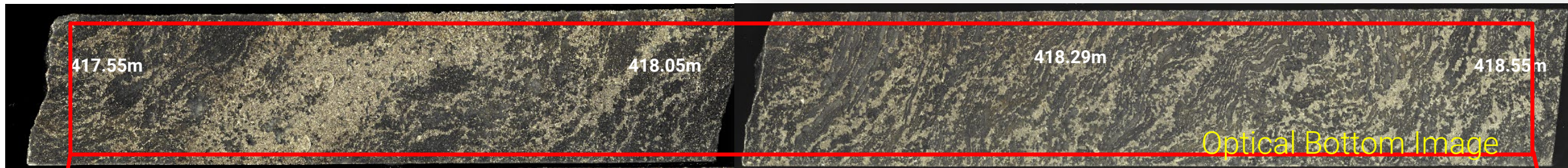
Mineralogical



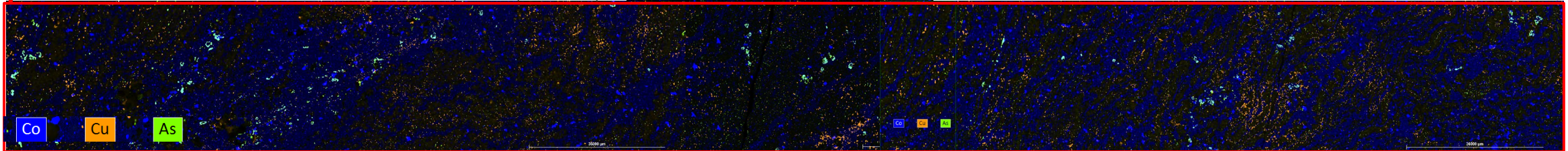
Finland: Co-Au Deposit

Drill Core Analysis

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.

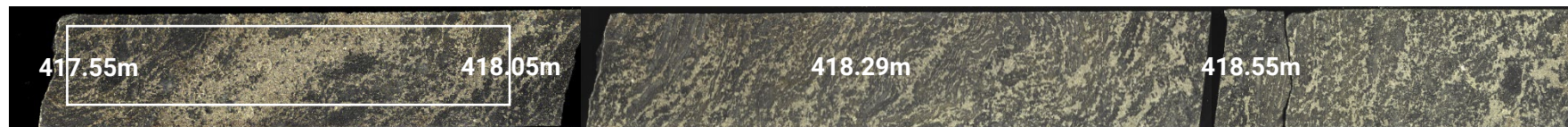
Finland: Co-Au Deposit

Drill Core Analysis

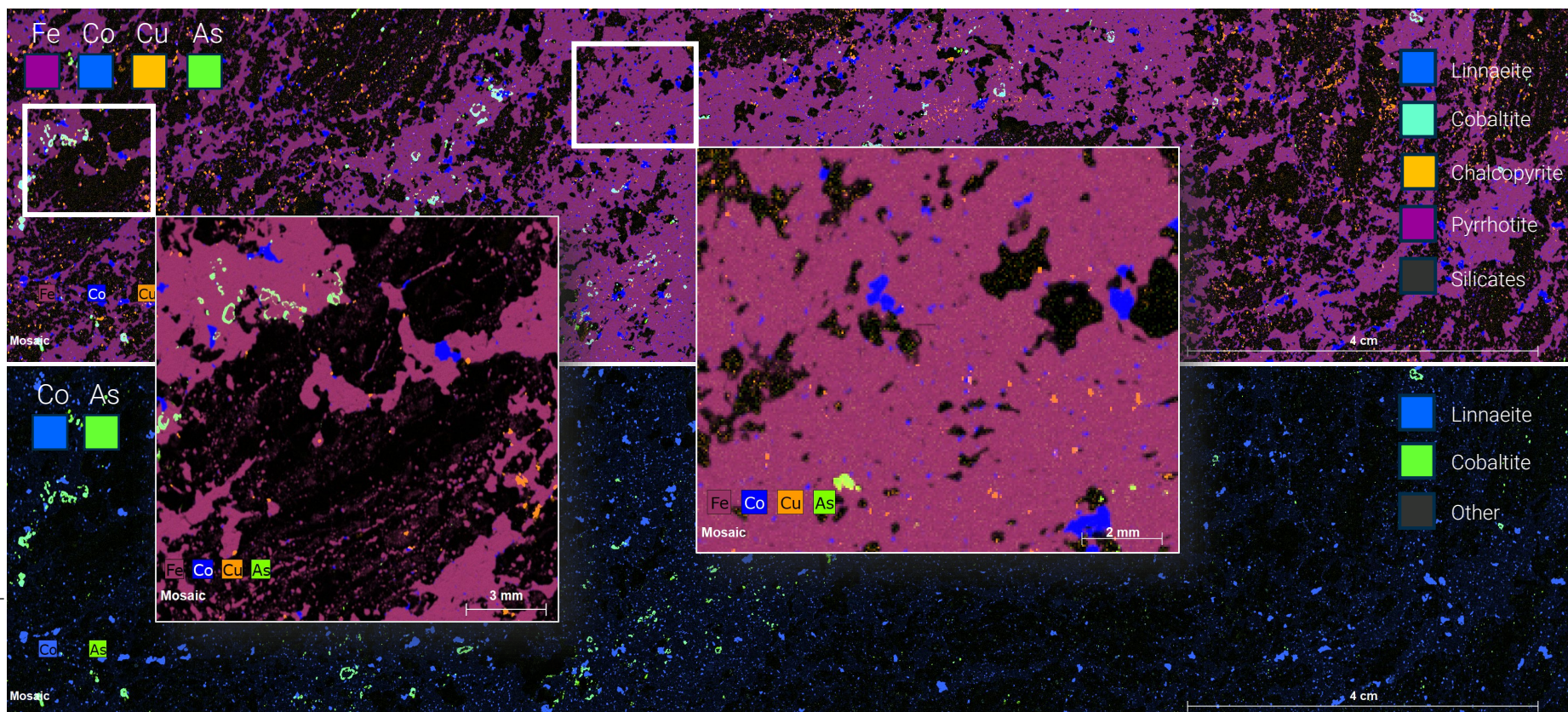
PAL0163 – 417.55m

Extreme Detail

Identification of key elements of interest

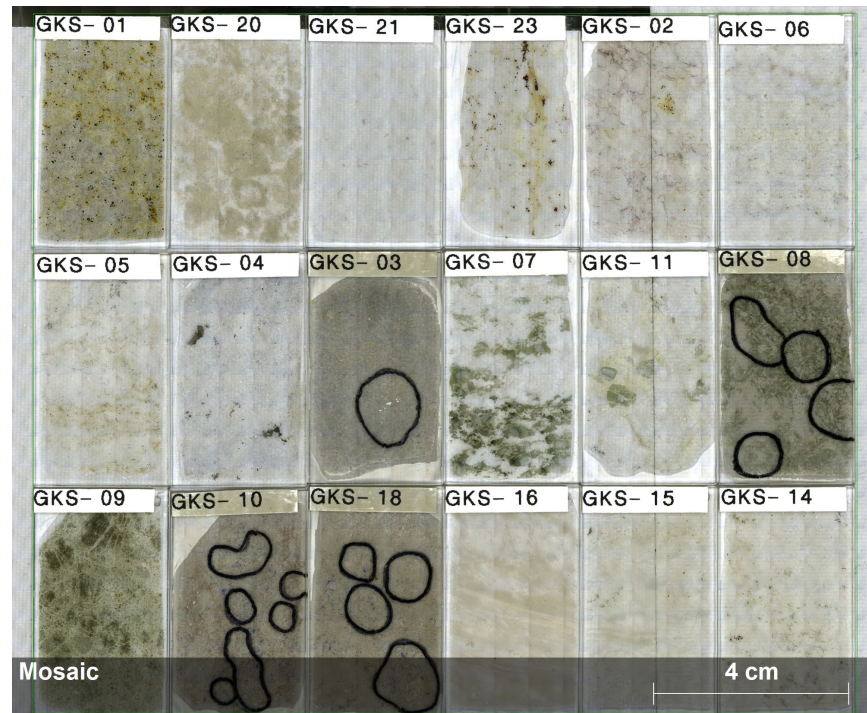


Overlaid Mixed Element images can lead to mineral identification



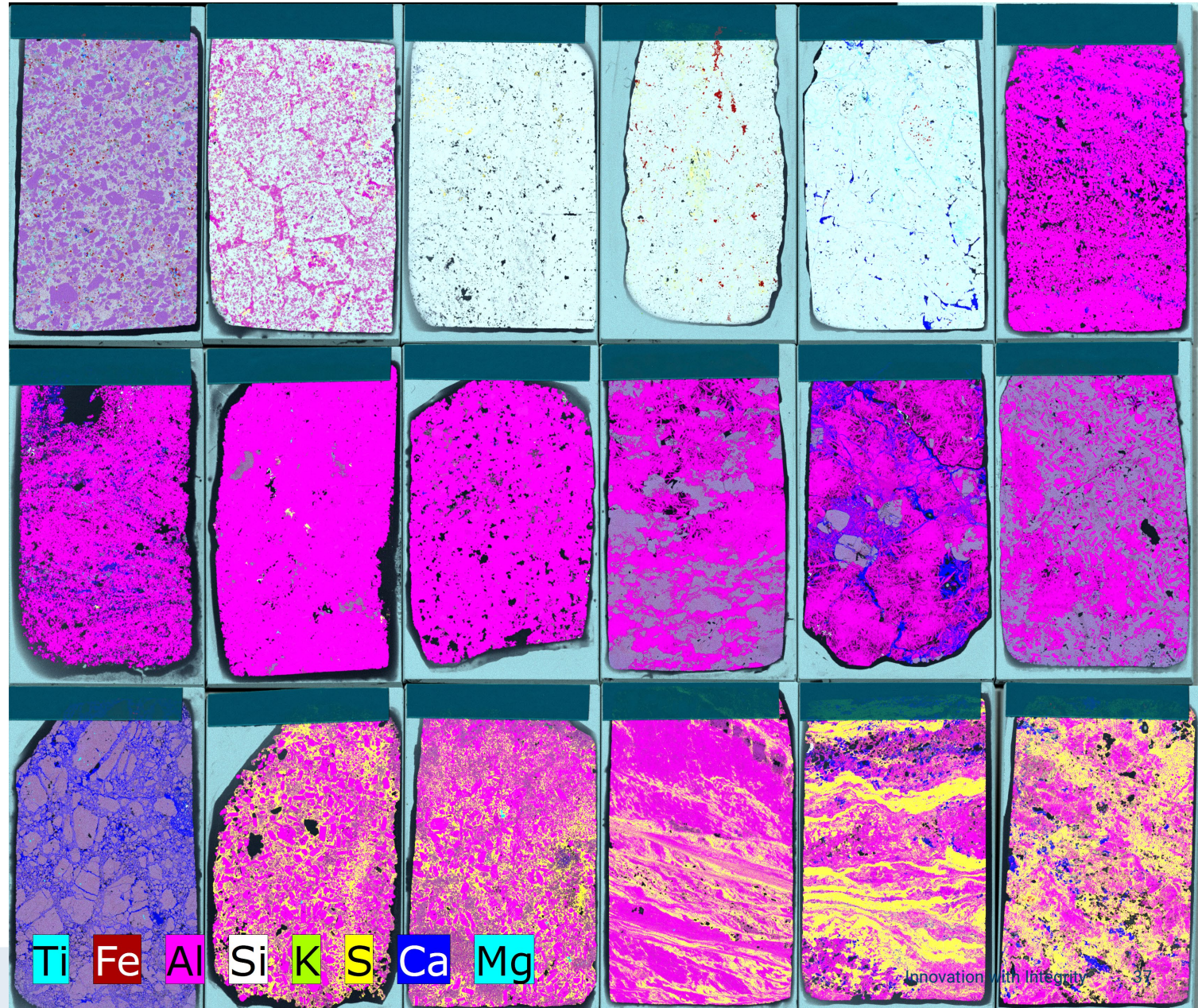
High resolution scans can identify textures and associations

Sapphires: Micro-XRF – Thin Sections

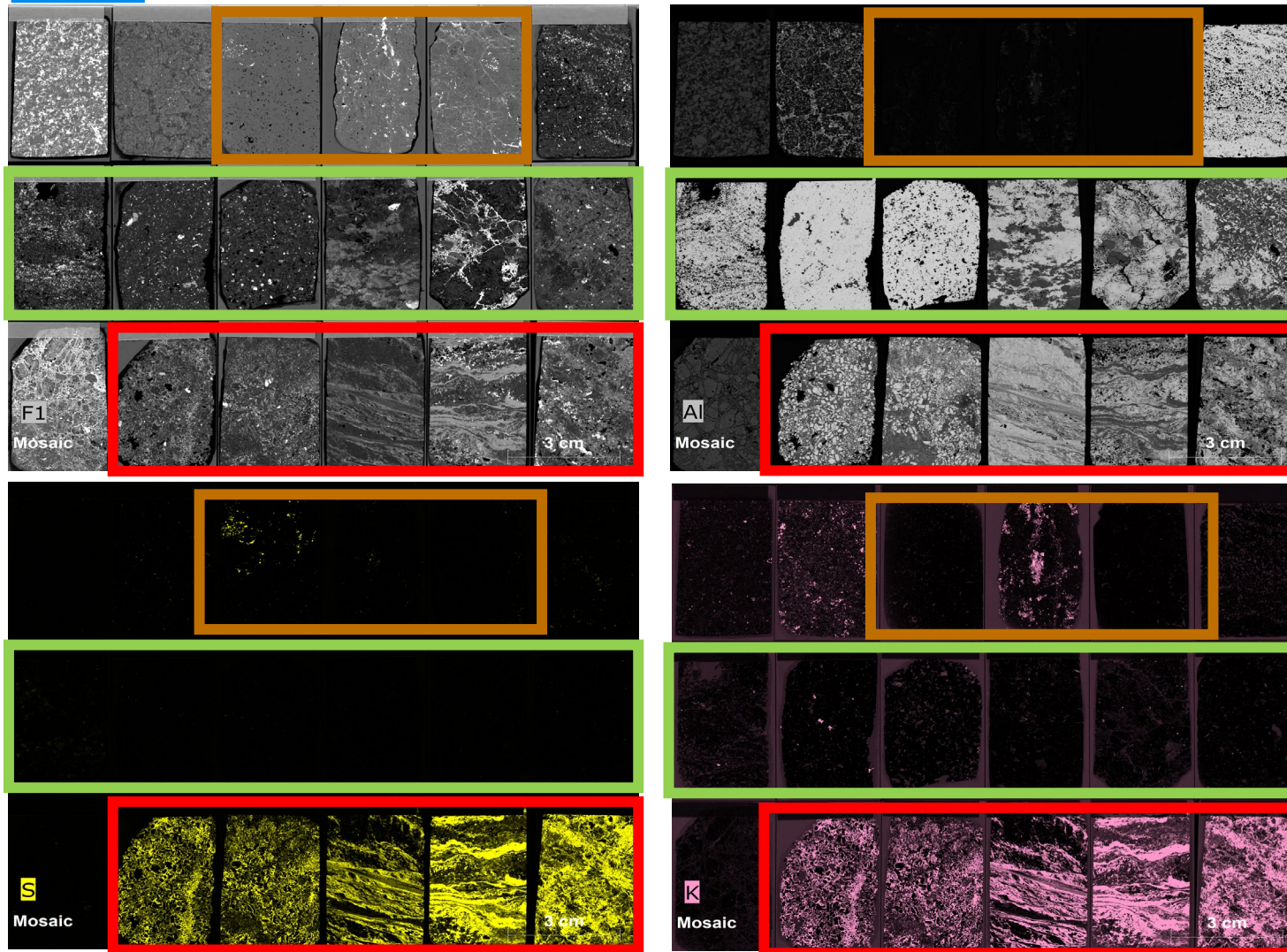


Analysis of 18 Thin Sections that represent the various lithologies observed at Portezuelo de Pajas Blancas.

Above: Optical Image
Right: Overlaid Element Intensity Maps



Sapphires: Micro-XRF – Thin Sections

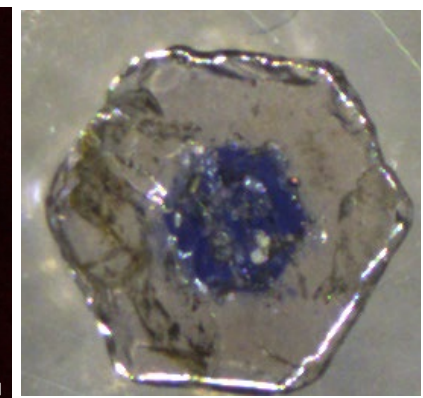
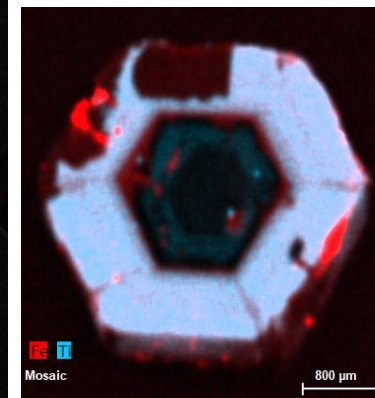
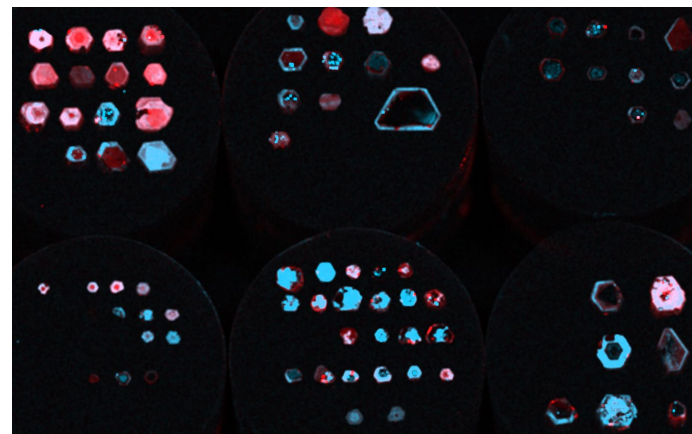
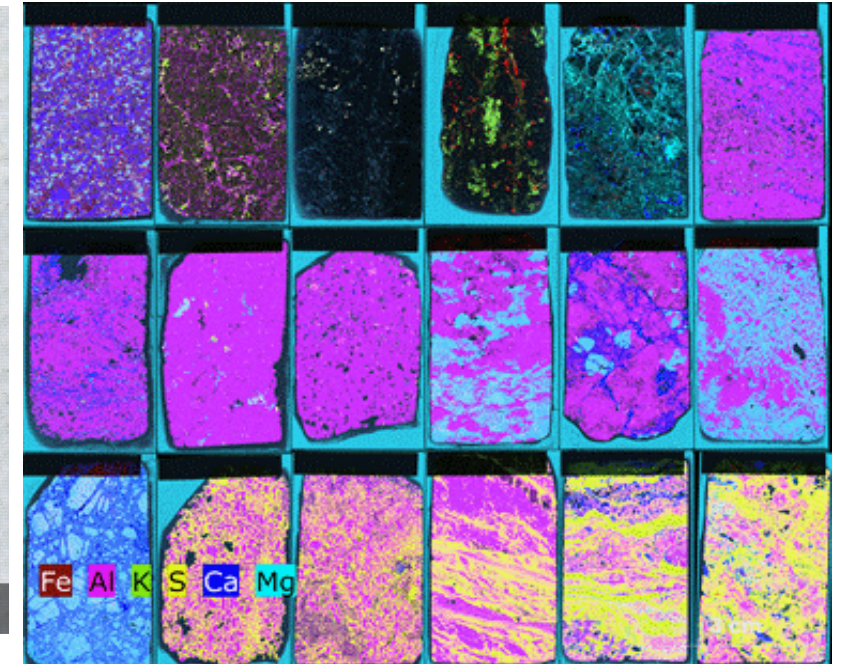
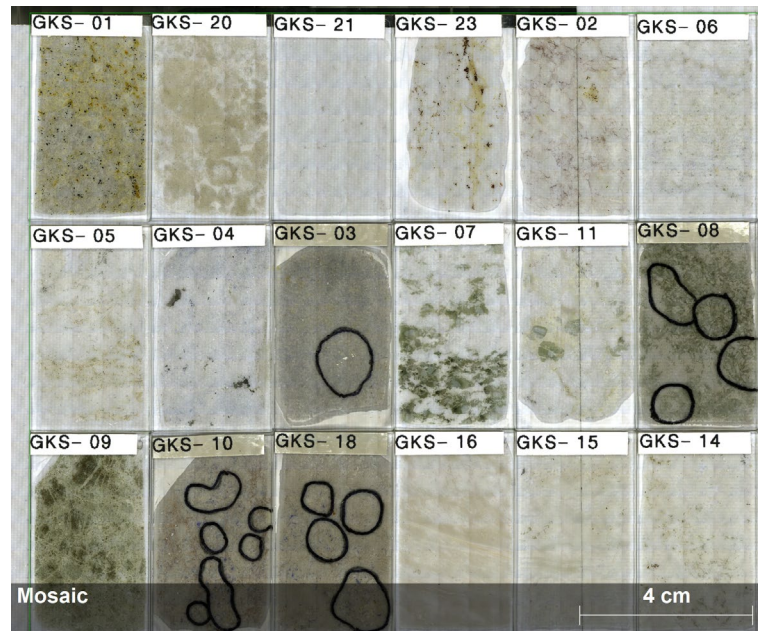


Analysis of 18 Thin Sections that represent the various lithologies observed at Portezuelo de Pajas Blancas. Individual Element Intensity Maps.

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

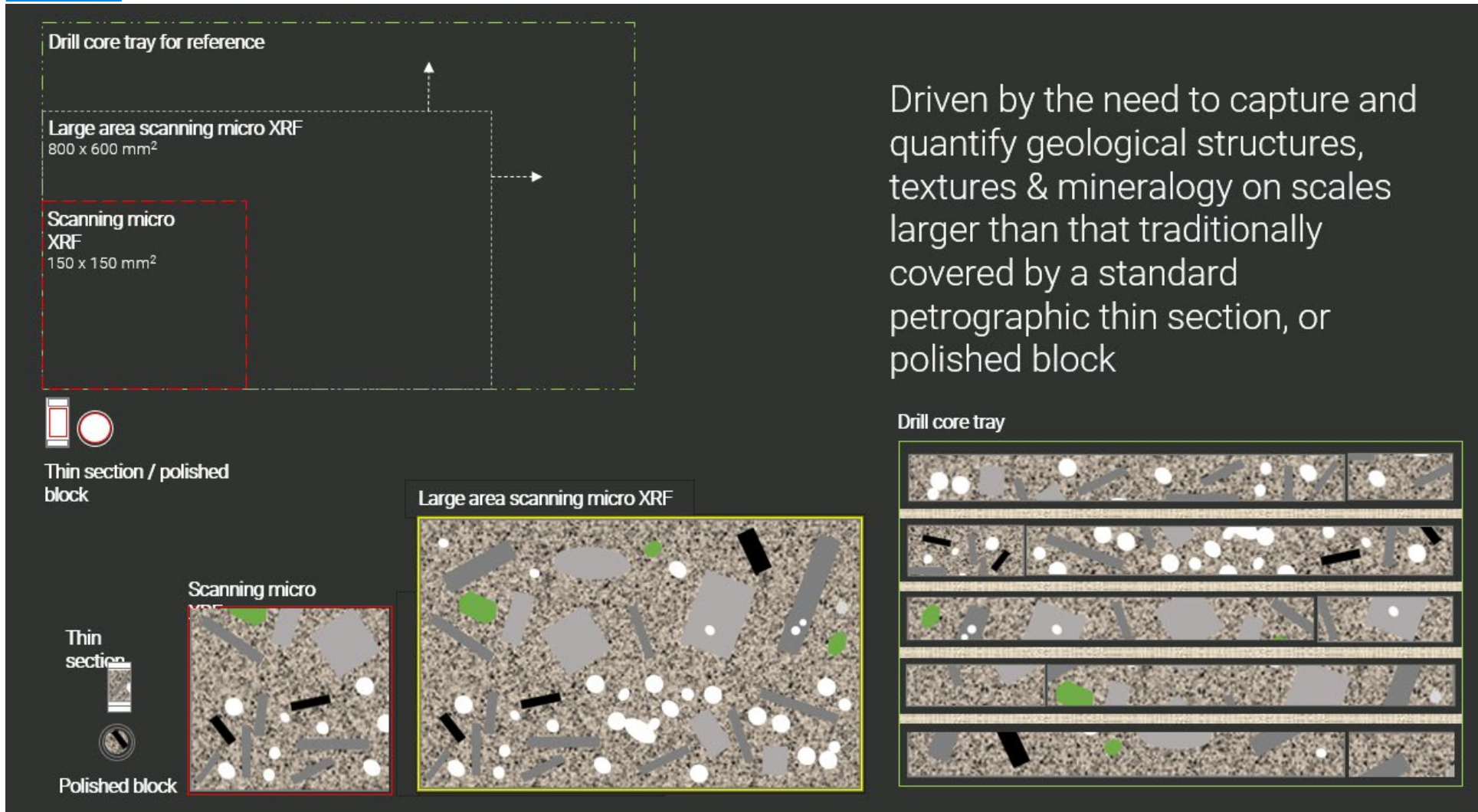


Micro-XRF (M4 TORNADO) can analyze samples of different sizes:
Left: Field Rock Samples to
Top Right: Thin Sections to
Bottom Right: Individual Crystals

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 department
 - 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



The diagram illustrates a multi-scale analytical workflow. At the top left, a 'Drill core tray for reference' is shown with a dashed green border. Below it, a 'Large area scanning micro XRF' area of 800 x 600 mm² is indicated by a dashed white border. Within this, a 'Scanning micro XRF' area of 150 x 150 mm² is shown with a solid red border. To the right, text explains the need to capture and quantify geological structures, textures, and mineralogy on scales larger than those covered by traditional methods like petrographic thin sections or polished blocks. Below the diagram, a 'Drill core tray' image shows a horizontal strip of rock with various mineral grains. Below that, a 'Large area scanning micro XRF' image shows the same area with mineral grains highlighted in green and black. To the left, a 'Thin section / polished block' image shows a small area of the rock with mineral grains highlighted in green and black. Below that, a 'Thin section' image shows a small area of the rock with mineral grains highlighted in green and black. At the bottom left, a 'Polished block' image shows a small area of the rock with mineral grains highlighted in green and black.

Driven by the need to capture and quantify geological structures, textures & mineralogy on scales larger than that traditionally covered by a standard petrographic thin section, or polished block

Drill core tray

Thin section / polished block

Large area scanning micro XRF

Thin section

Polished block

Scanning micro XRF

Courtesy of GTK,
Alan Butcher



Micro-XRF Further Information

M4 TORNADO PLUS
Super-light Elements in micro-XRF

**XRF Mapping
Down to Carbon**
He-Purge for Sensitive Samples

Evaluating Greenfield and Brownfield Mining Exploration Projects using Micro-XRF (EN & PT)

This webinar will take place on November 28, 2023

Gem Sapphires: Understanding their Origins and Quality - The Benefits of Combining micro-XRF and SEM-EDS

On-Demand Session - 42 Minutes

Multiscale In-situ Non-destructive micro-XRF Scanning Analysis: Implications for ore Mineralogy, Petrogenesis and Micro-metallurgical Assessments

On-Demand Session - 60 Minutes

Minerals with X-ray Spectroscopy

the presence (or lack thereof) of information also enables an and the environment in which they record the genesis of the deposit locally, in the case of sapphires, a

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

On-Demand Session - 63 Minutes

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#Picoftthemonth
The Imilac Meteorite was discovered in the Atacama Desert (Chile) in 1822. It is one of the largest stony-iron pallasites ever found and is prized by co...see more

The Imilac Meteorite - one of the largest stony-iron pallasites ever f...

www.bruker.com/micro-xrf

Search for:
M4 TORNADO or
M4 TORNADO PLUS

Analysis of Geological Samples Using Micro X-ray

The micro-analysis of geological samples is common practice and provides valuable information on a scales, for example in mineral exploration and process mineralogy. The exploration process and subsequent metallurgical understanding occurs on scales that vary by numerous orders of magnitude. An important part of this chain is the transition from samples collected in the field to analysis in the laboratory. The micro-XRF bridges these challenging scales of observations allowing micro-analytical interpretations to be related to field samples (i.e. visually), as well as enabling the ability to select appropriate samples for detailed micro-analysis, which is often costly and time-consuming.

In this webinar we will present examples of the characterization of cobalt-rich samples using a genome approach that employs geo-analytical techniques to achieve multi-scale, multi-modal, and multi-dimen information. The focus of this study is on the analysis of drill core sections and their interpretation, from an up-scaling and down-scaling viewpoint using micro-XRF as a key component of the overall workflow result is a new perspective on commercial mineralogy incorporating details about liberation of both on gangue minerals.

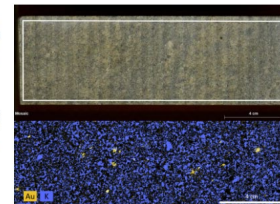
Element Analysis in Mineral and Metallurgical Processes

In many economic deposits the element or mineral of interest is a trace component. However, the ability to identify 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. Specifically, the examples shown will highlight the difference between a trace element and trace mineral and the analytical tools to best support the ultimate project goal.

A combination of micro-XRF and SEM-EDS/WDS will expand your workflow analytical capabilities. Micro-XRF is ideal for analyzing large areas on the micro scale and is a powerful tool for identifying both trace elements or minerals, even directly from drill core samples. In contrast, SEM analysis allows a higher spatial resolution required to understand the elemental and mineralogical processes at a high magnification. The SEM-EDS/WDS combination allows analysis at high spectroscopic resolution, even for trace elements.

The benefits and capabilities of each will be discussed to ultimately provide the best workflow for your analytical needs.

There will be a 15-minute Q&A session where our experts will answer your questions.



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Dutch tin-glazed tiles were used in Amsterdam since the 17th century for decorating architectural surfaces. The most famous were made in Del...see more

Reconstructing the history of a 17th Century Delfware Tile using micr...

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search for:
#micro-XRF or
#Picoftthemonth

More Information

For more information, please contact us:

info.bna@bruker.com

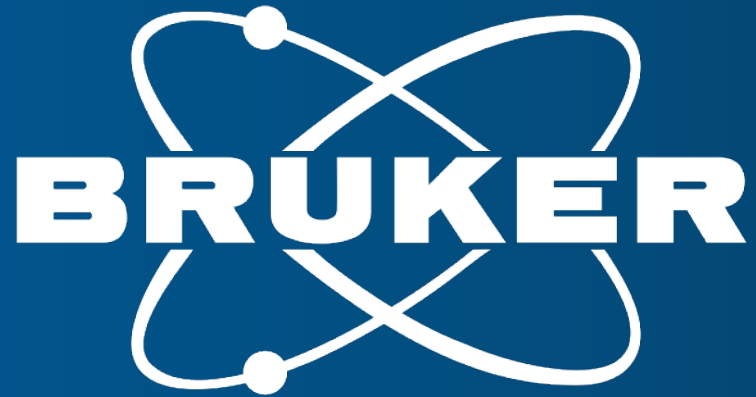
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or

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