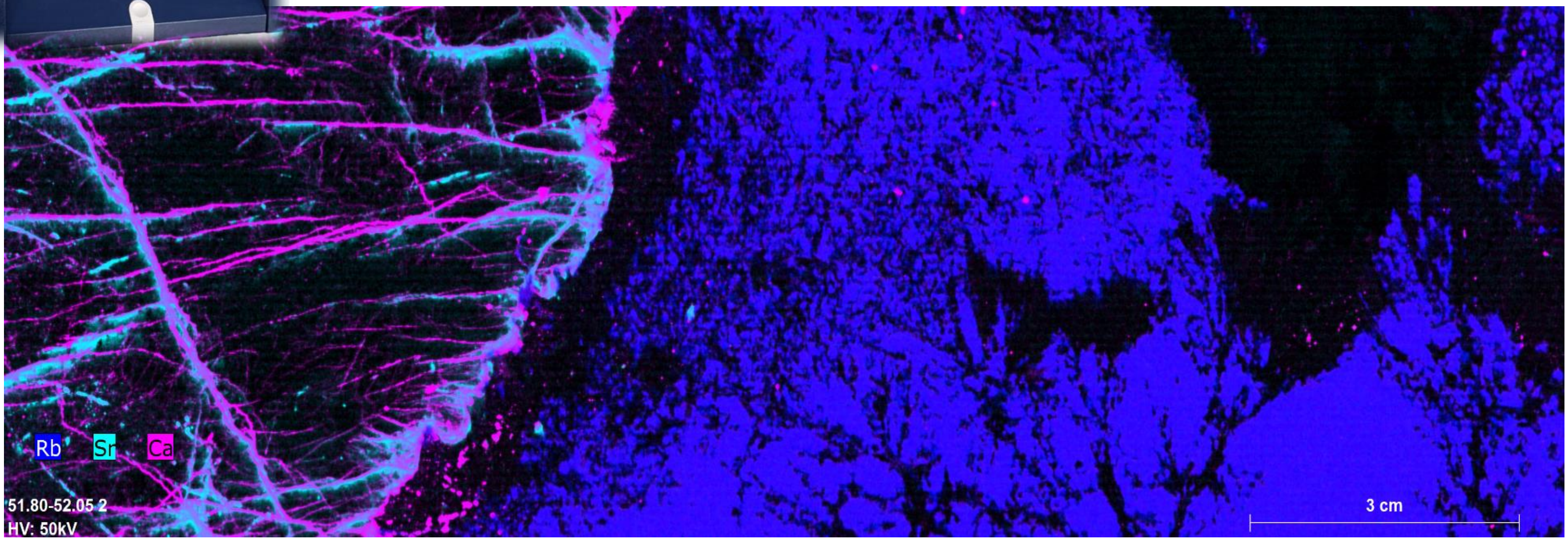
Application of micro-XRF to characterise diamond drill-core from lithium-caesium-tantalum pegmatites

By Naomi Potter

Micro-XRF!



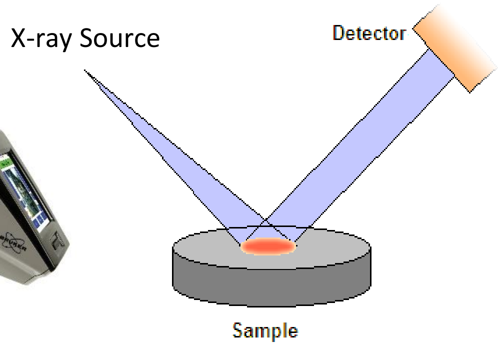
Reminder about XRF

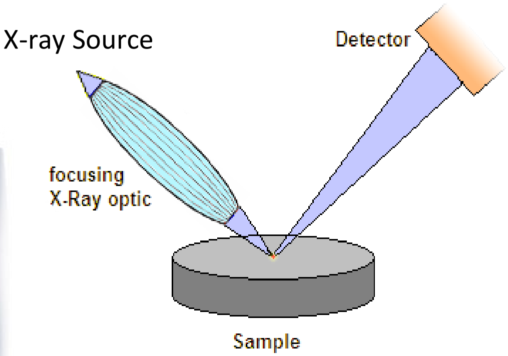
Portable XRF

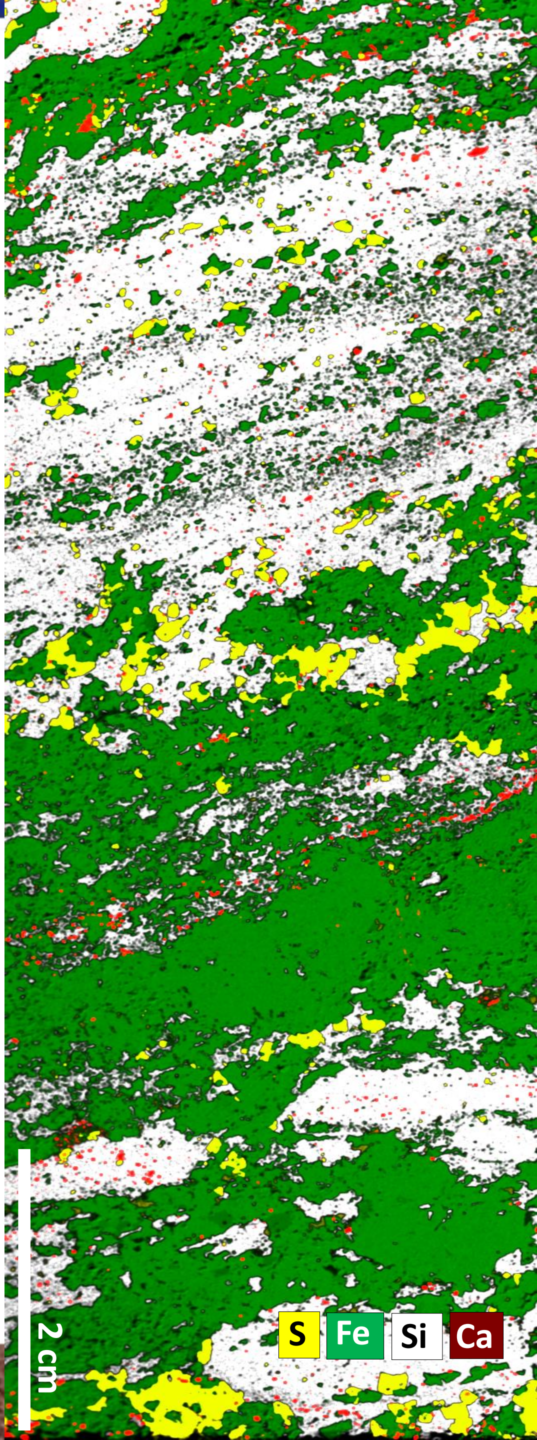
- Portable spectrometer
- Open beam
- 8 mm, 5 mm, 3 mm spot size
- Samples should be homogenized*
- Focus on quantification in 1D
- Na^{11} to U^{92}(TRACER)
- Mg^{12} to U^{92} (TITAN)

Micro-XRF

- Lab spectrometer
- Interlocked system
- 25 µm spot size
- Can quantify but focused on 2D maps
- Na^{11} to U^{92} (M4)
- C^{6} to U^{92} (M4 Plus)







Benefits of µXRF

- Non-destructive
- Minimal sample preparation required
- No carbon coating
- Versatile range of sample types
- Mapping size up to 16 x 19 cm
- Detection limits down to ppm levels
- Qualitative and quantitative analysis
- Mineral maps

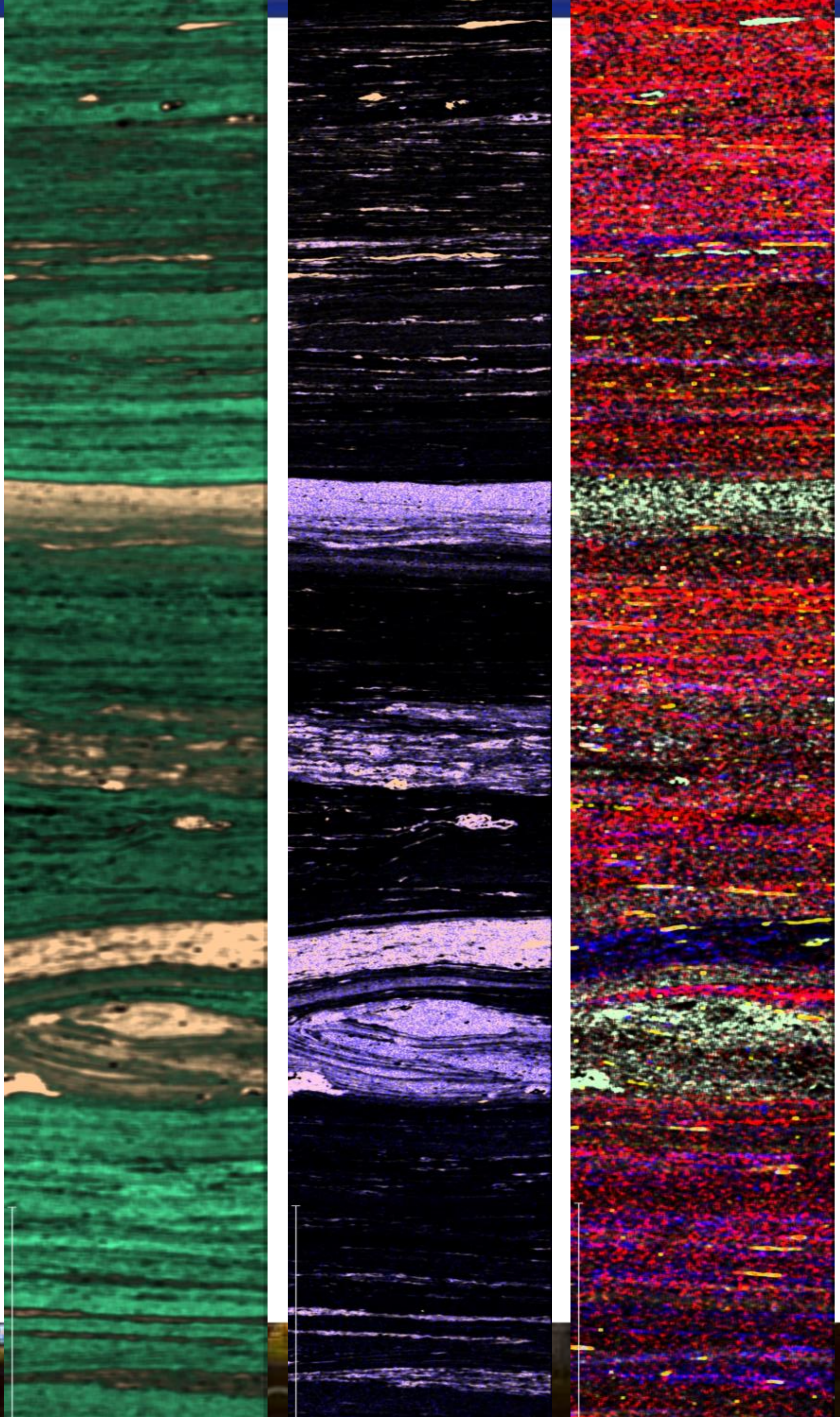
Element compositional maps

- Full X-ray spectrum for each pixel
- “On-the-fly” measurements
- Quantitative and qualitative
    - Element distribution and relationships
    - Fluid pathways
    - Alteration and weathering textures

Ca Si Carbonates vs. silicates

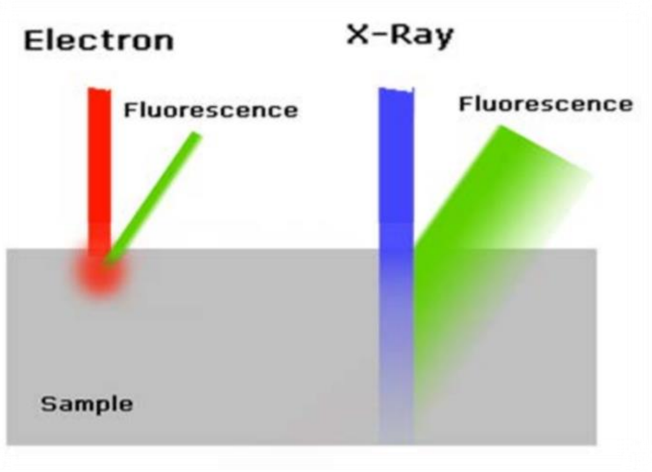
Ca + Mg = Dolomite

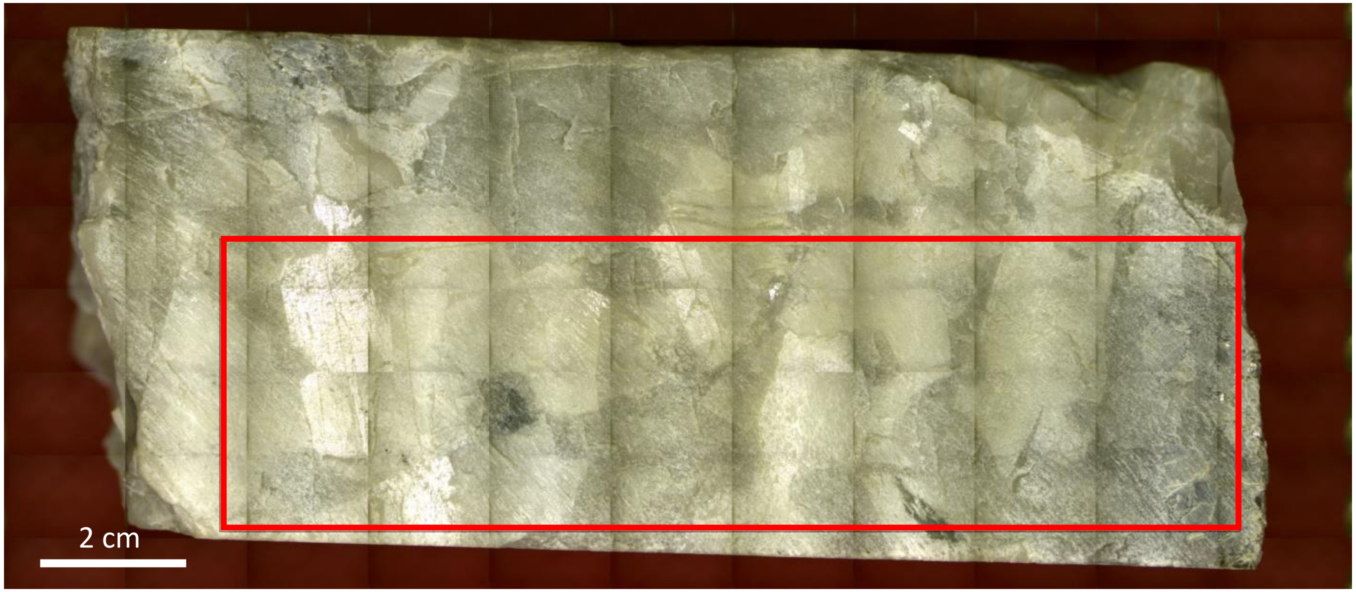
Mo Ni V Zn Some trace metals with an affinity for clays?



Mineral mapping

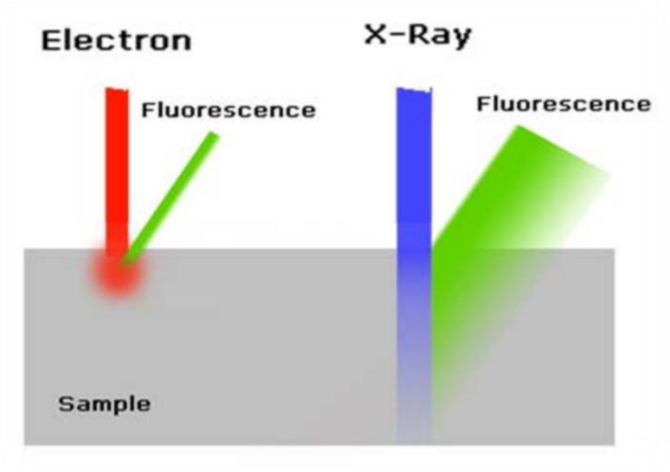
- Digital images and surface profiles
- Particle and grain size distributions
- Mineral identification and modal minerology

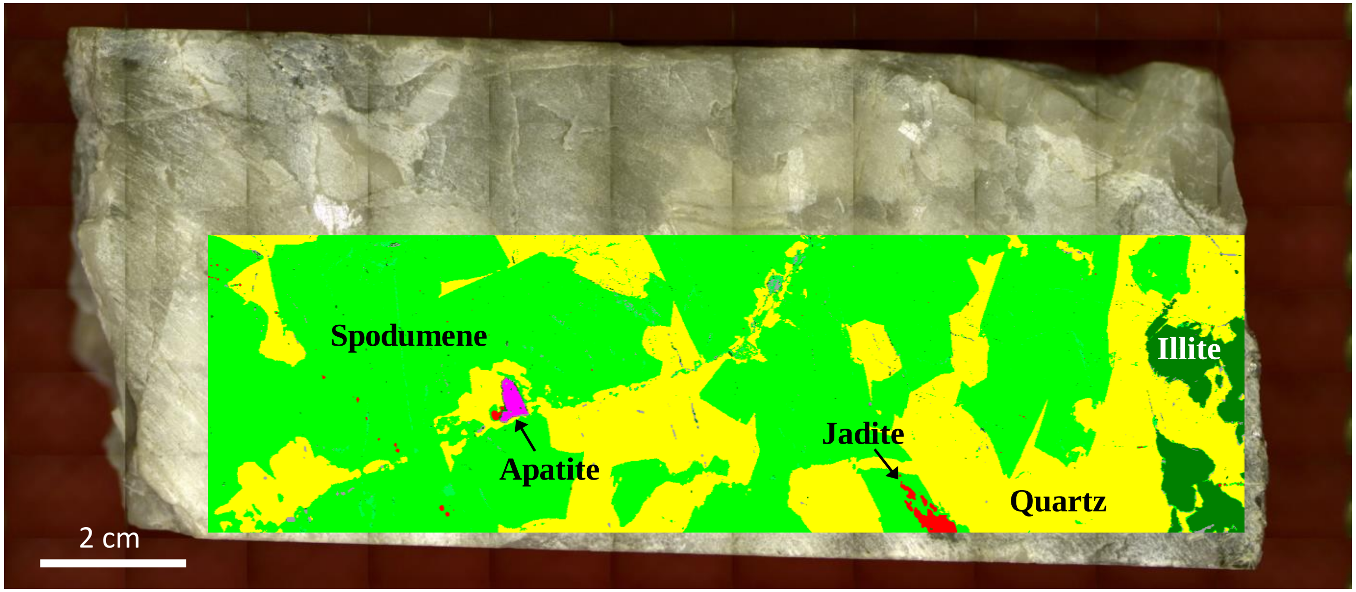




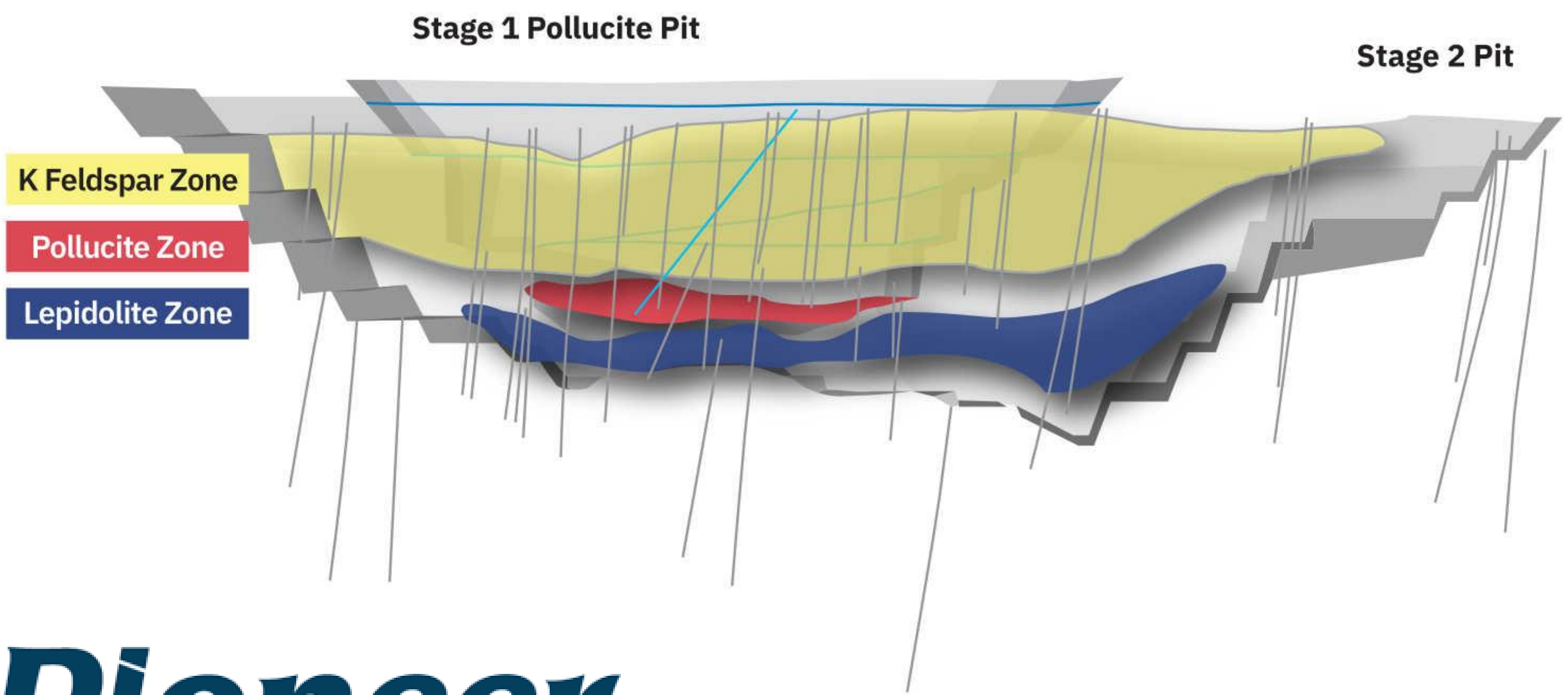
Mineral mapping

- Digital images and surface profiles
- Particle and grain size distributions
- Mineral identification and modal minerology





Sinclair Caesium Deposit



Pioneer RESOURCES LIMITED

Workflow

Collect Core Samples

Geologic description
of core and samples.
- number?

pXRF Core Scanning

Semi-quantitative chemistry and mineralogy. Samples pulped and analysed.
- number?

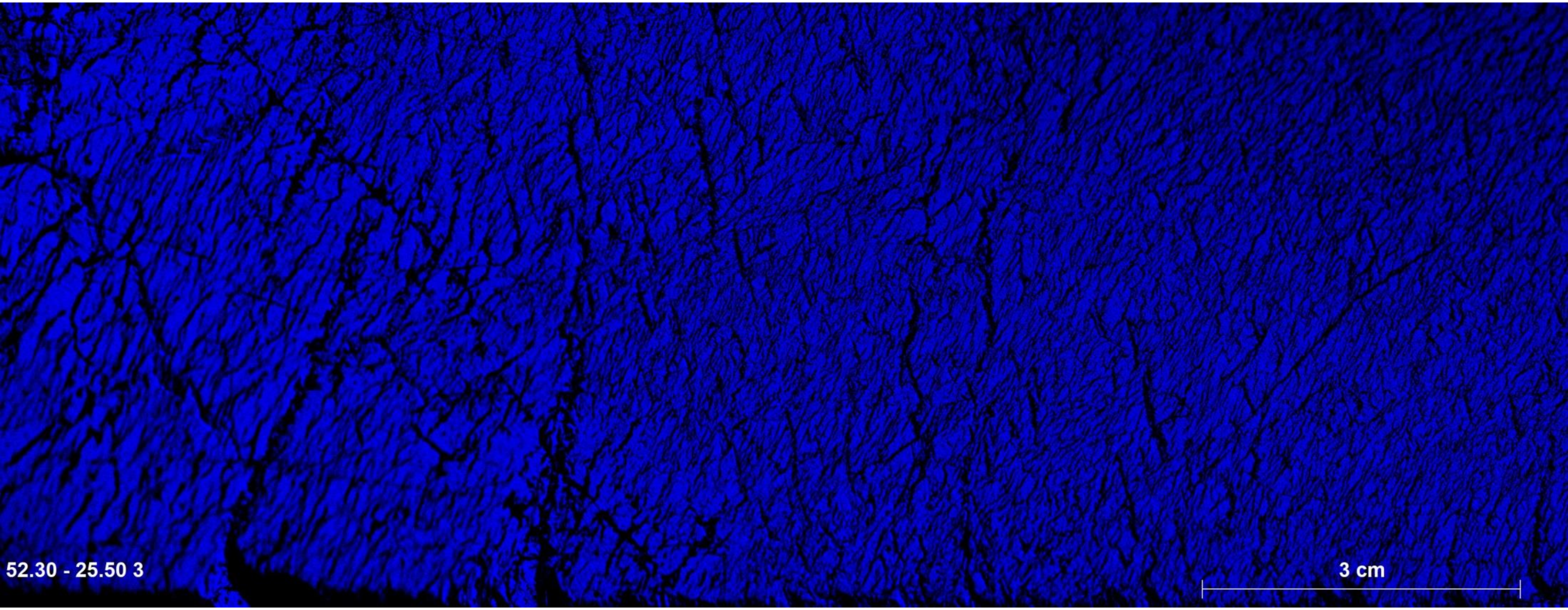
Micro-XRF
Selective Scanning

Qualitative chemistry and micro-textures to answer specific questions. Non-destructive analysis of core up to 15 cm in length.

Microcline

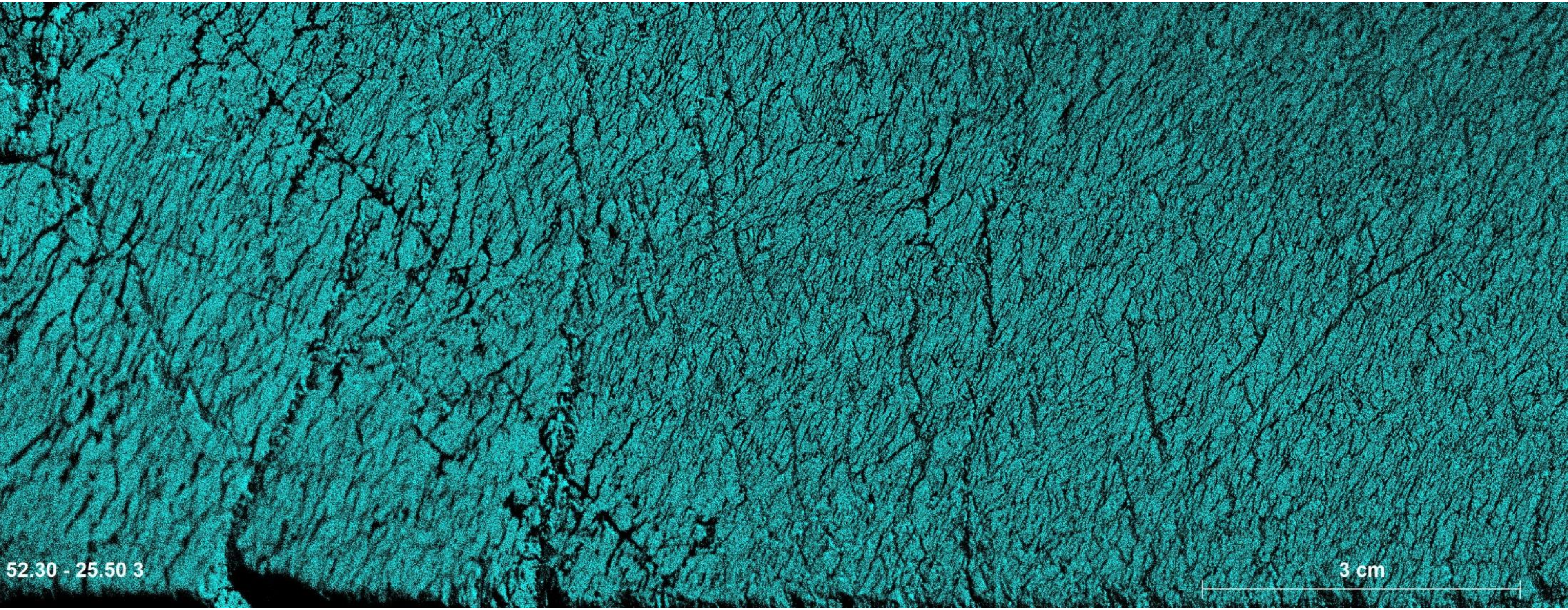
Microcline

K



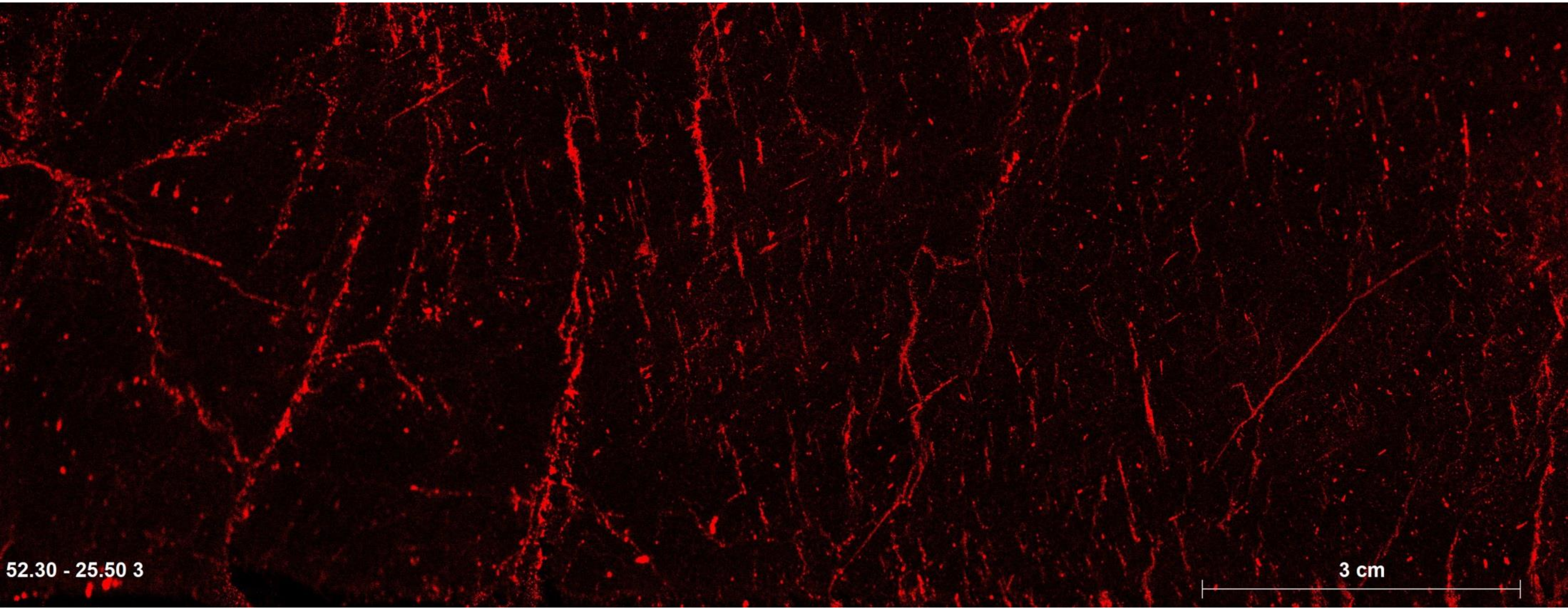
Spot pXRF K2O: 9.67wt%

Ca



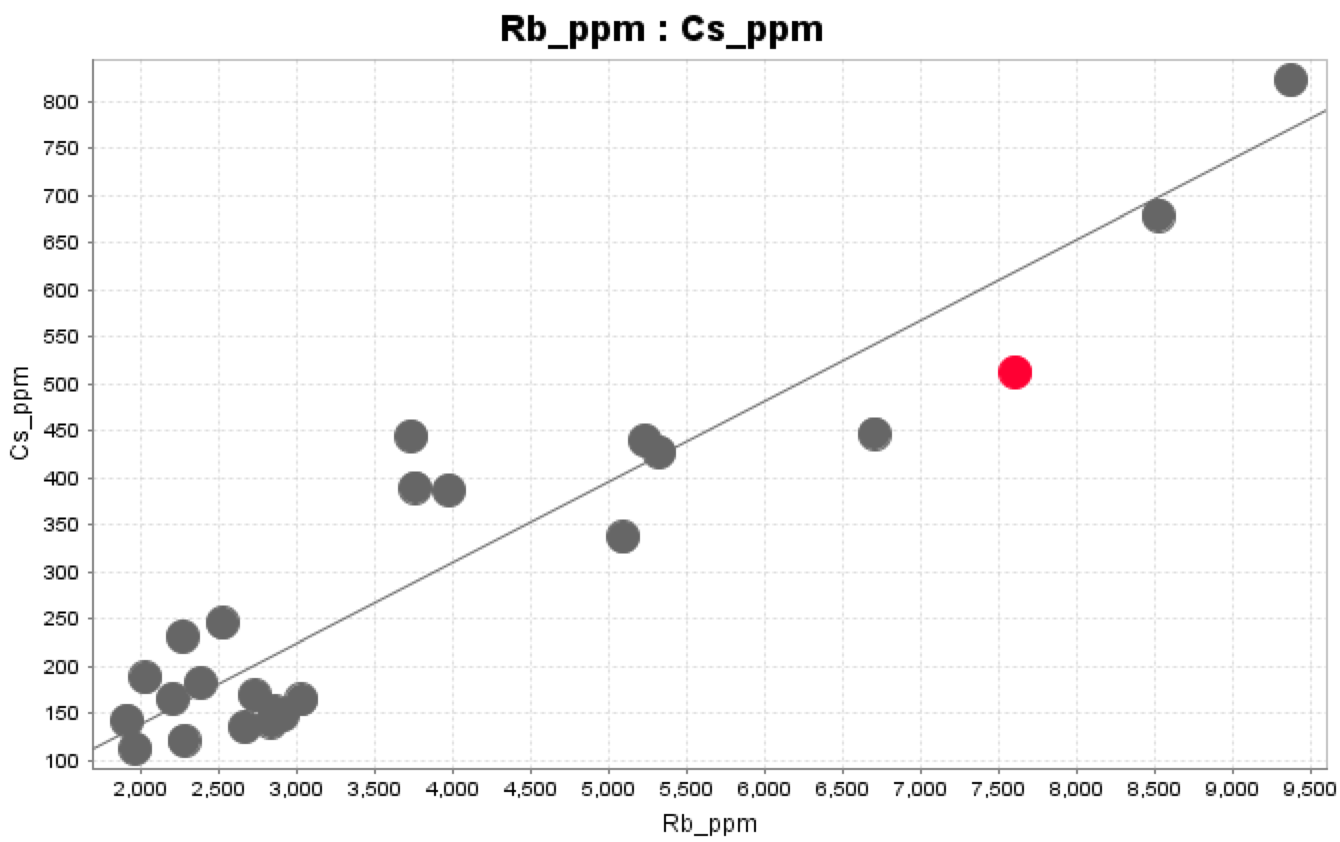
Spot pXRF CaO: 0.11 wt%

Fe



Spot pXRF Fe: 7040 ppm

Next question…



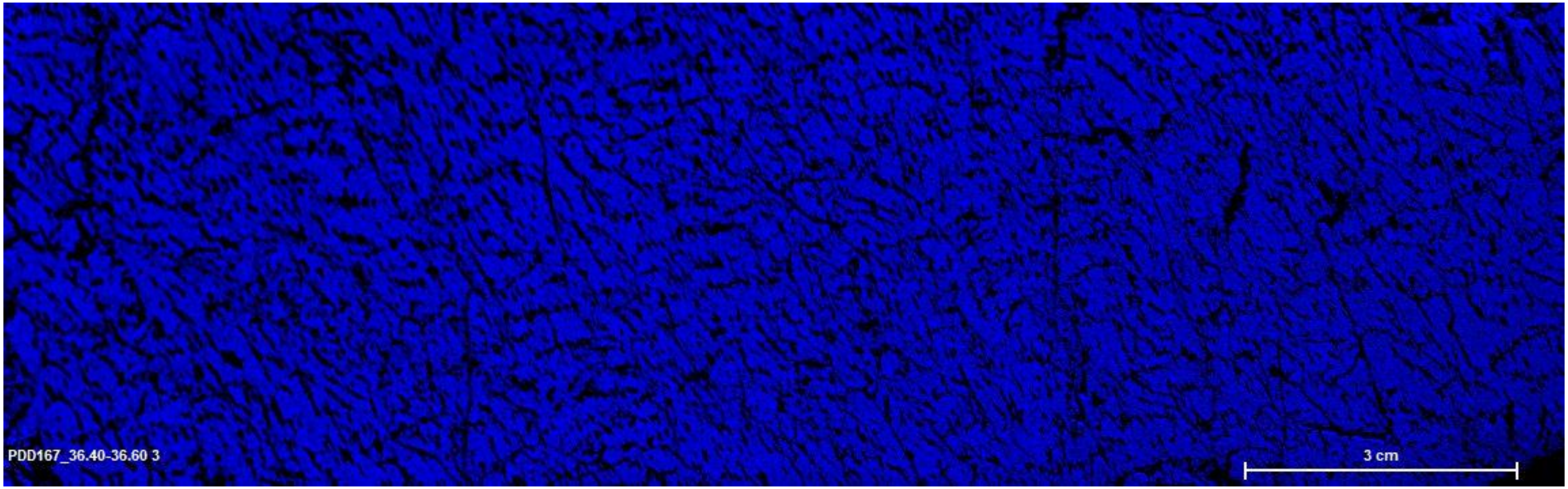
Microcline

18 cm

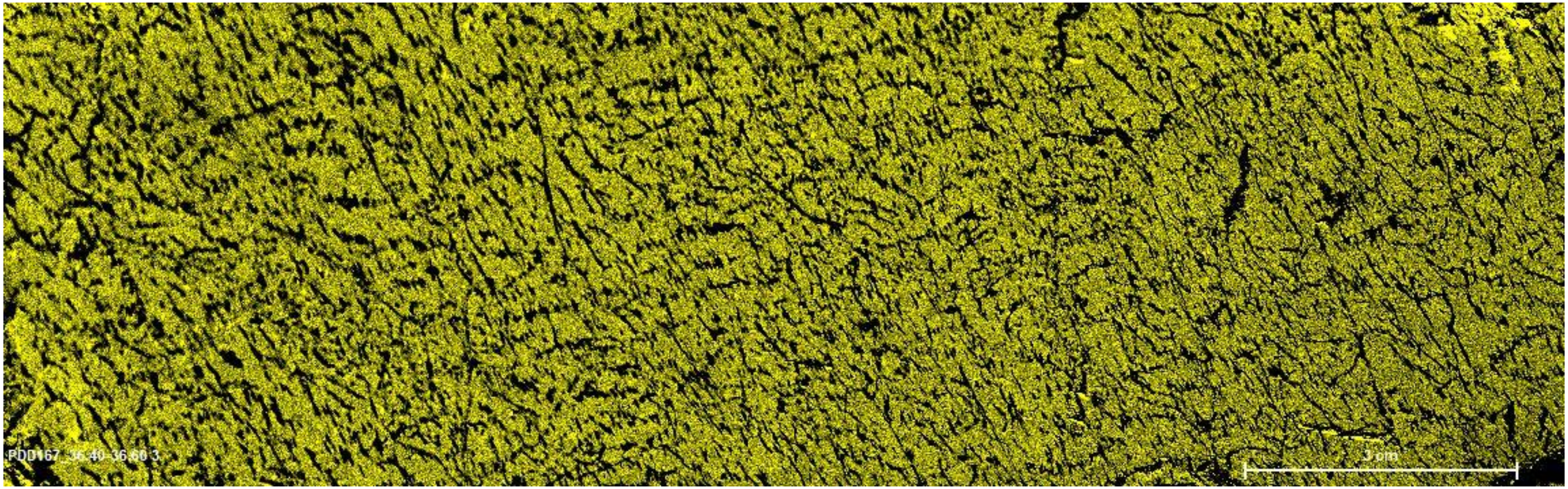
Microcline

18 cm

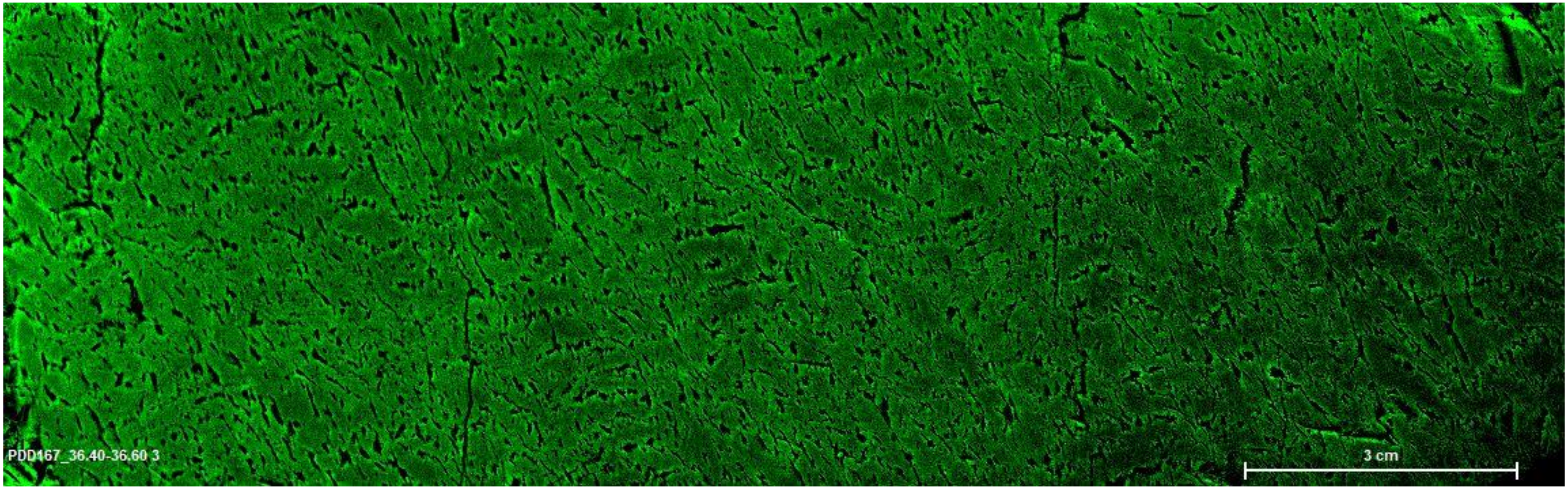
K



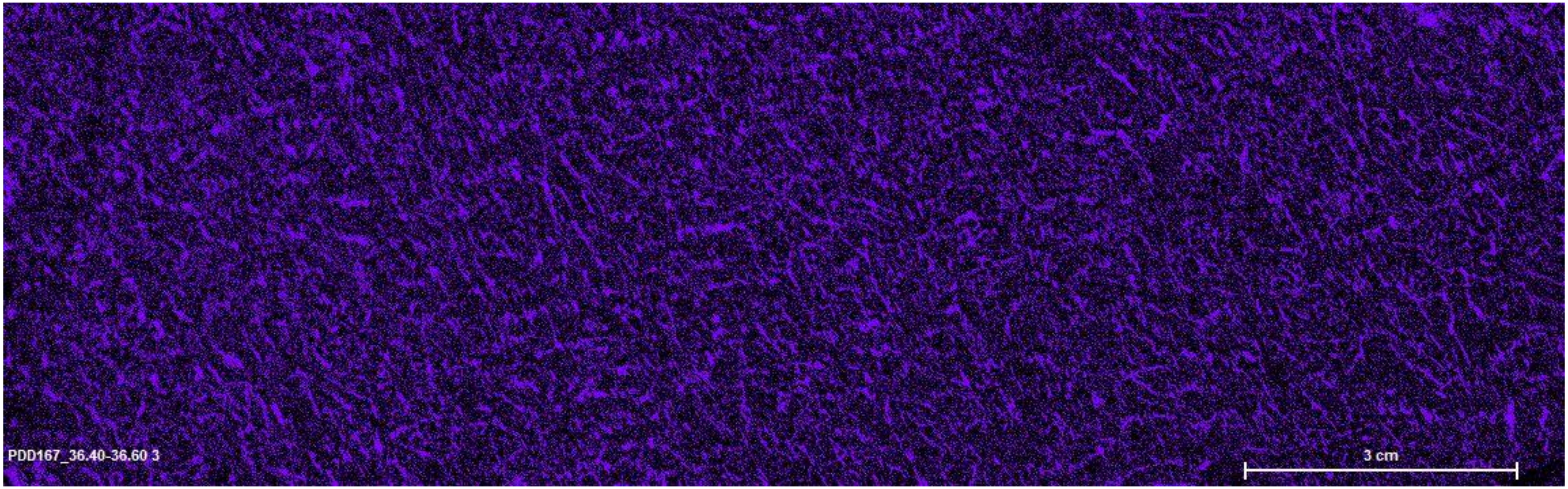
Ca



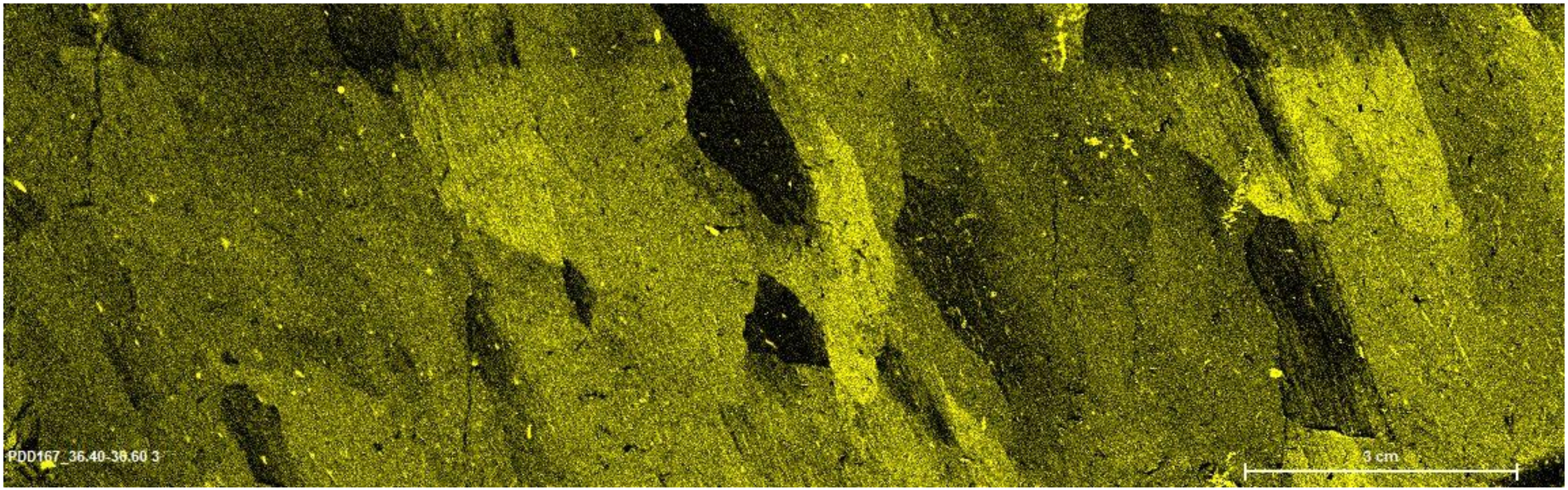
Rb



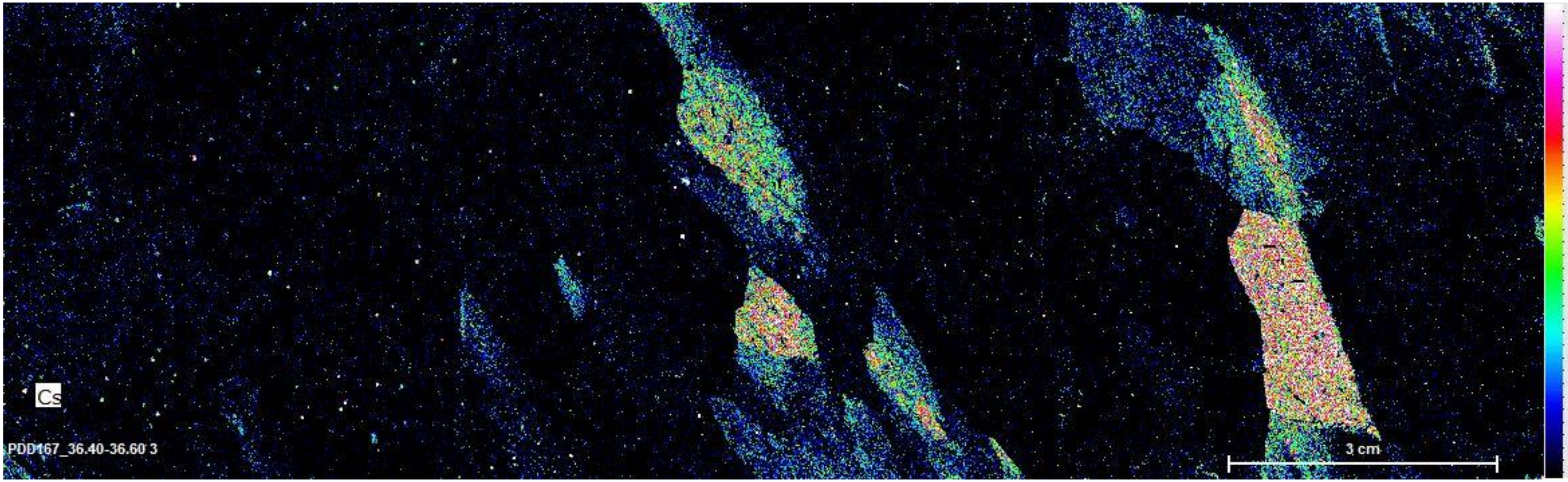
Na



Mn

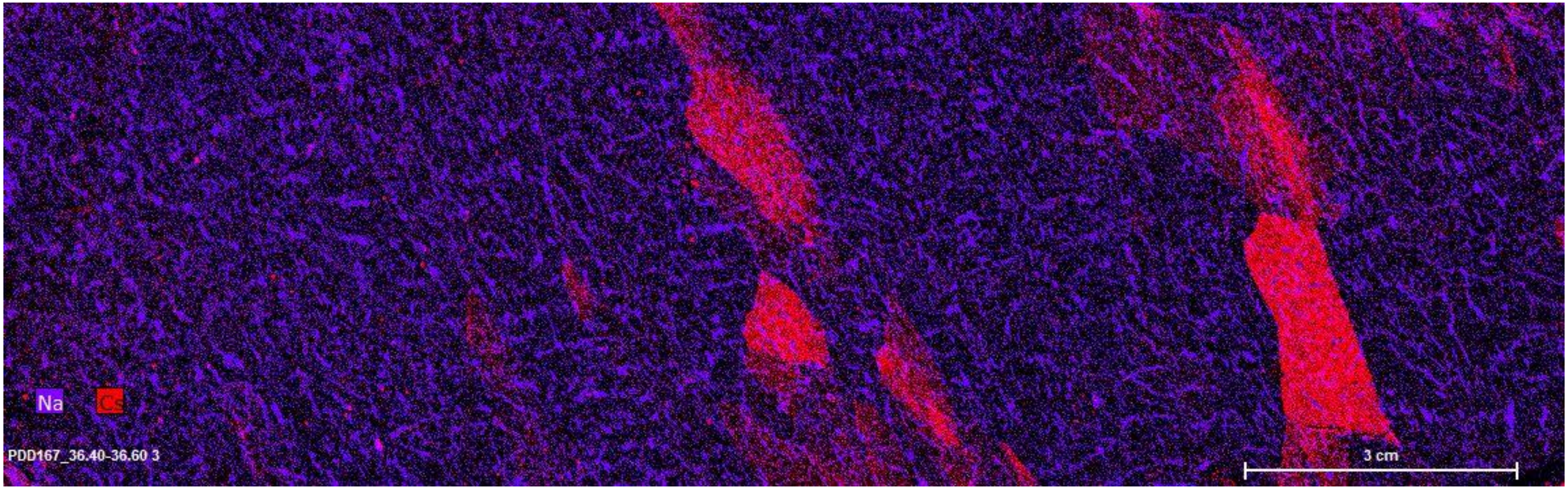


Cs



Cs - Na

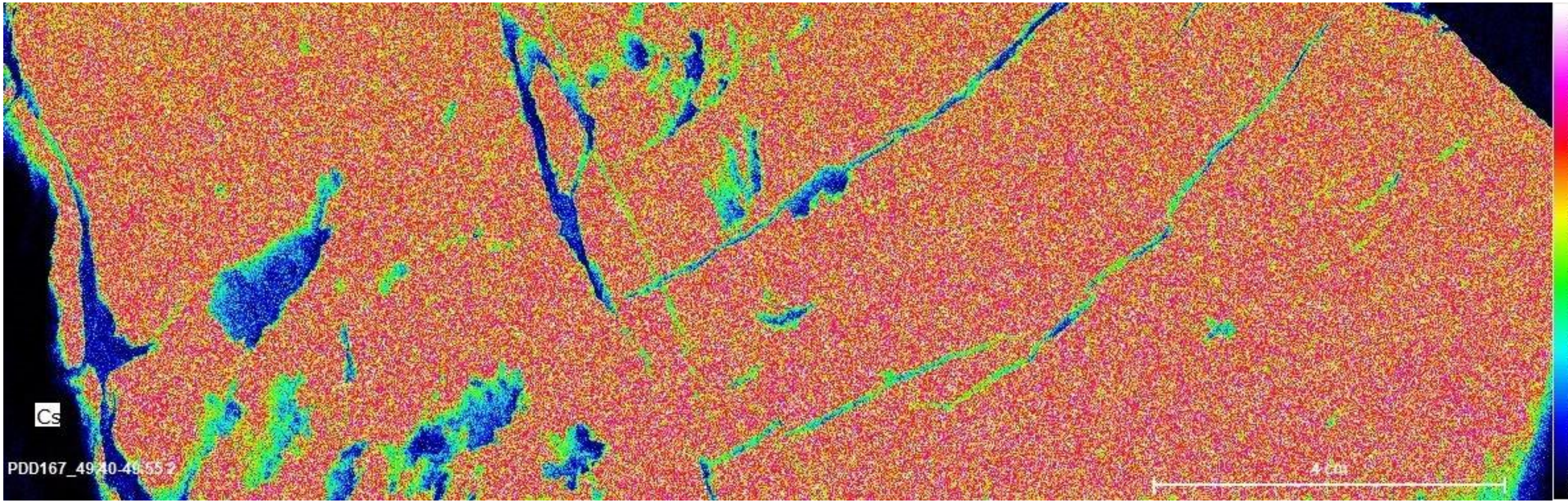
Time to make a Cs-Rb version of this?



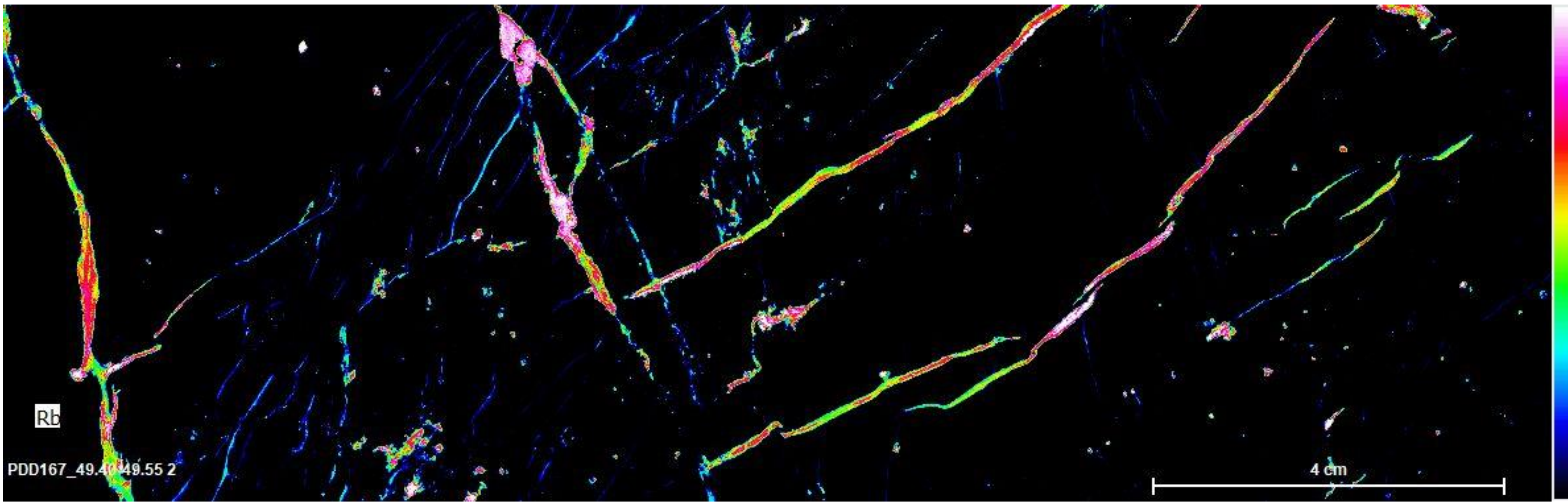
Pollucite

17.5 cm

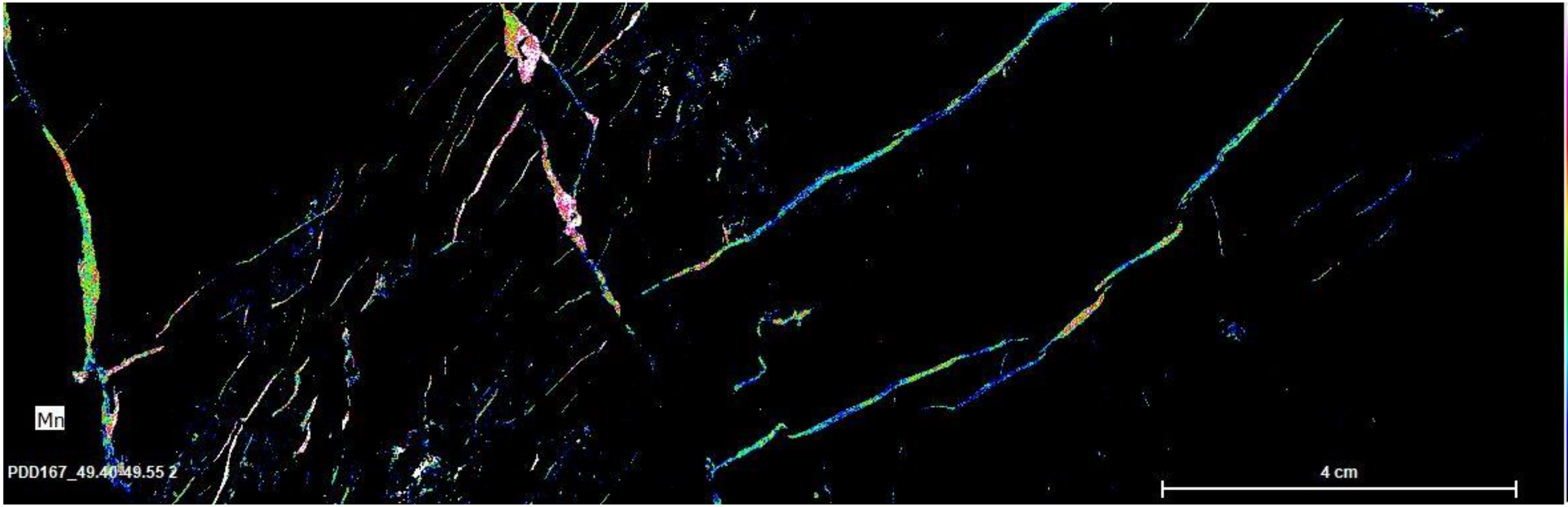
Cs



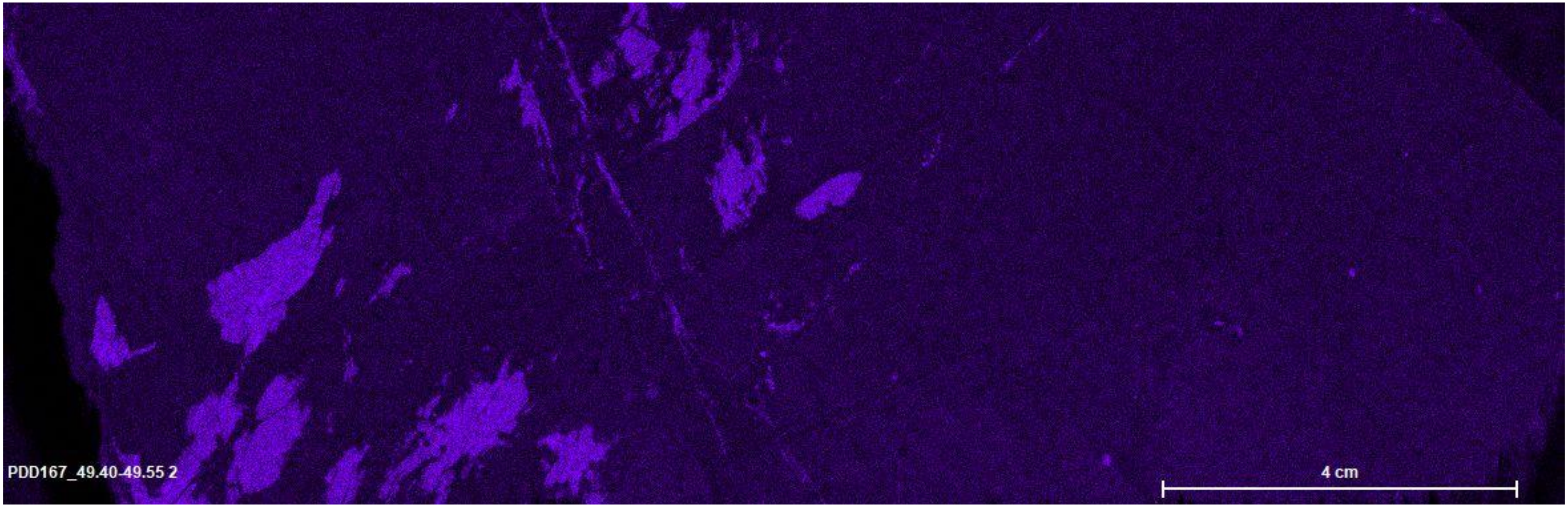
Rb



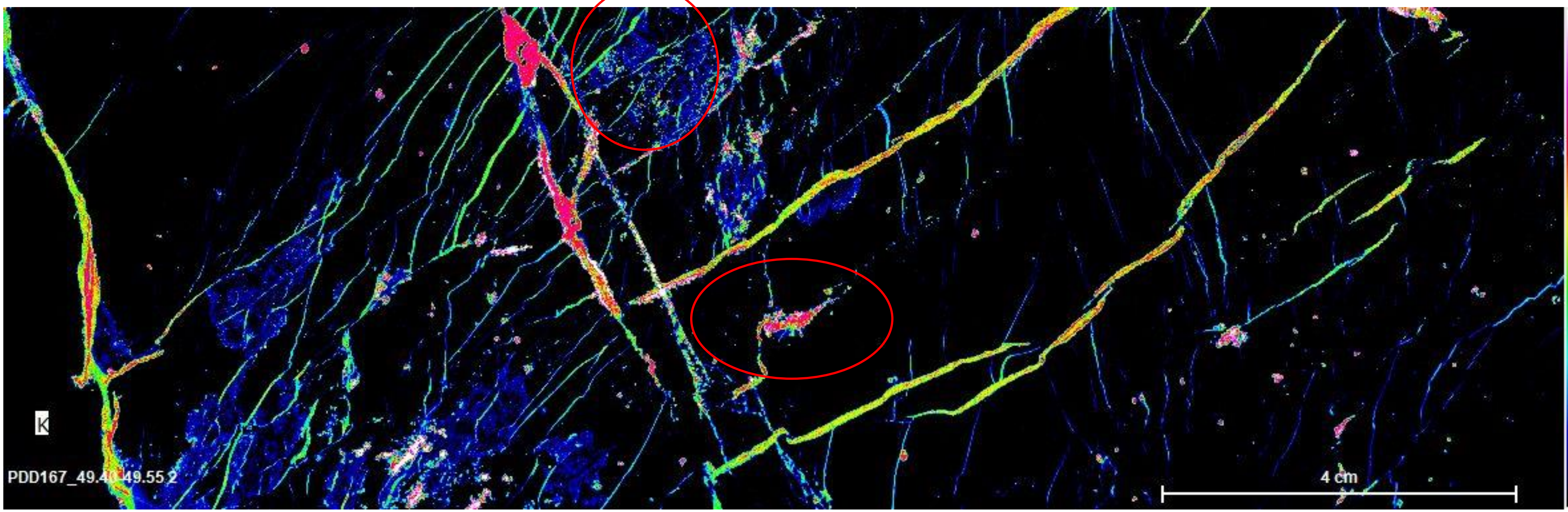
Mn



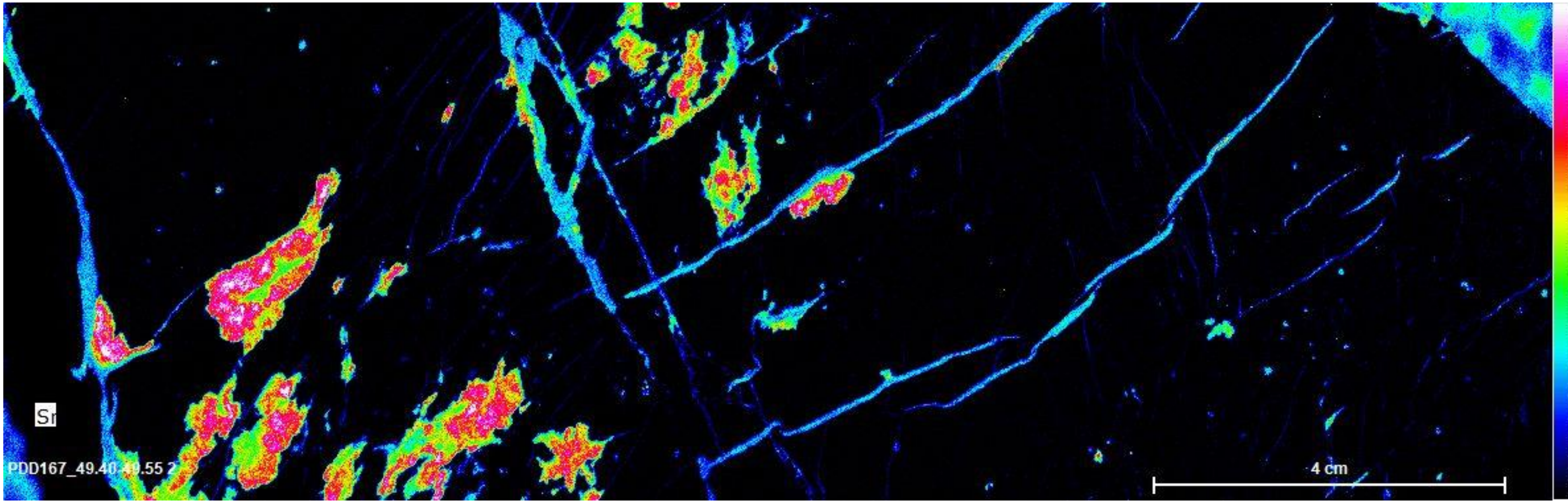
Na



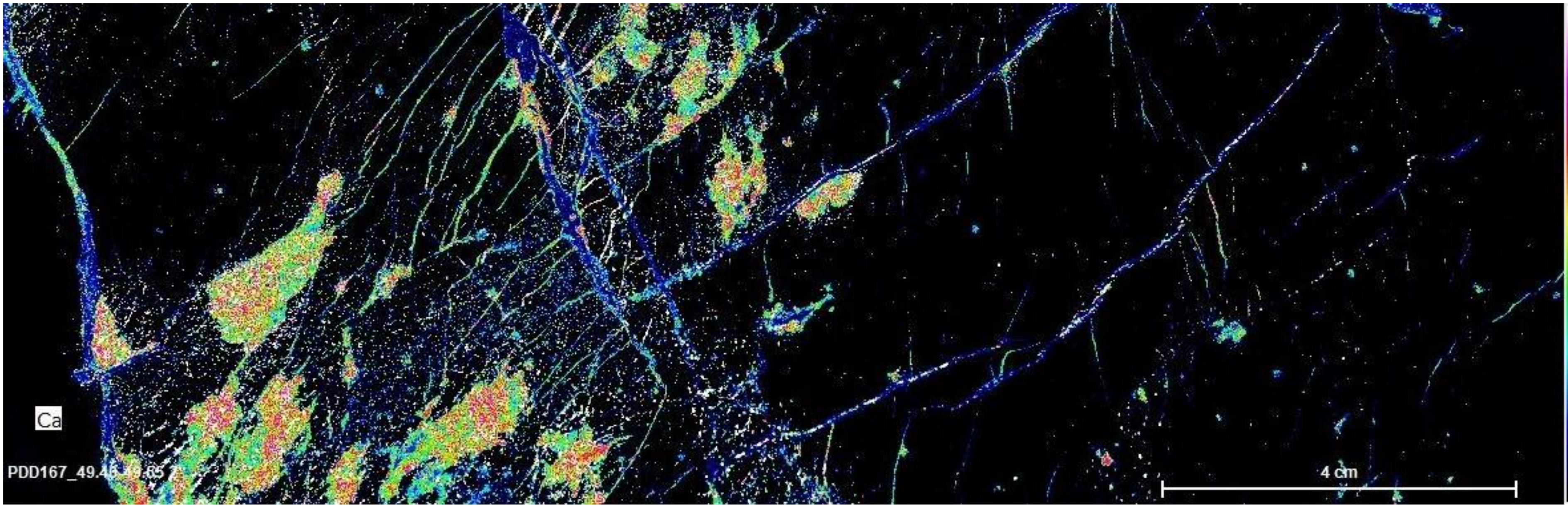
K



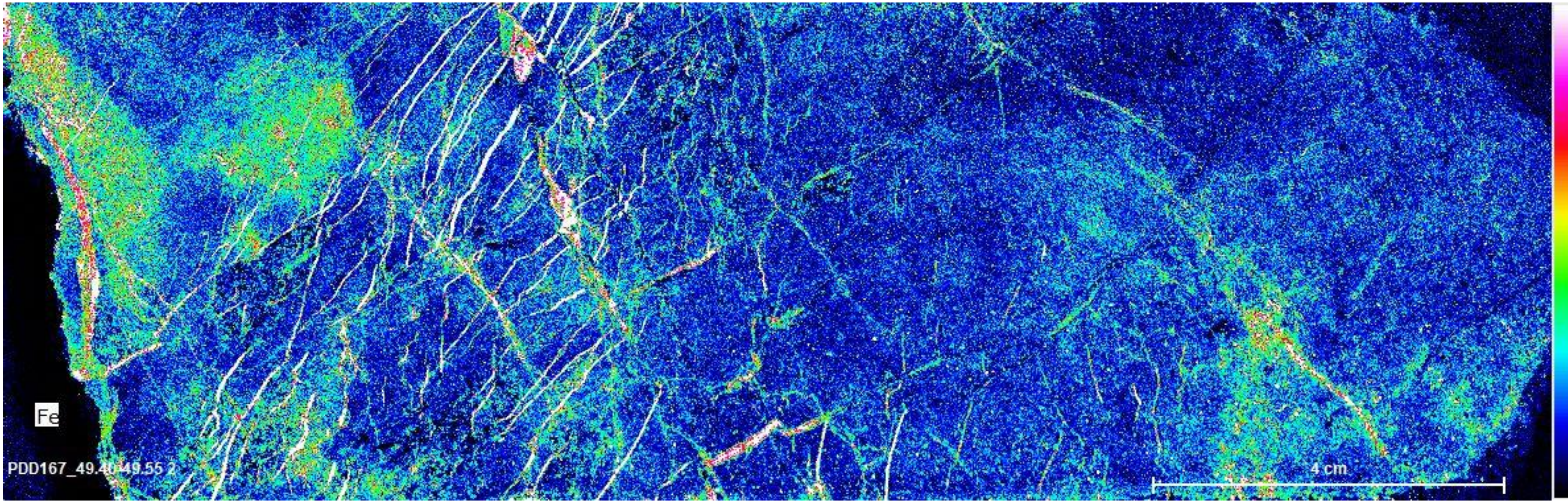
Sr



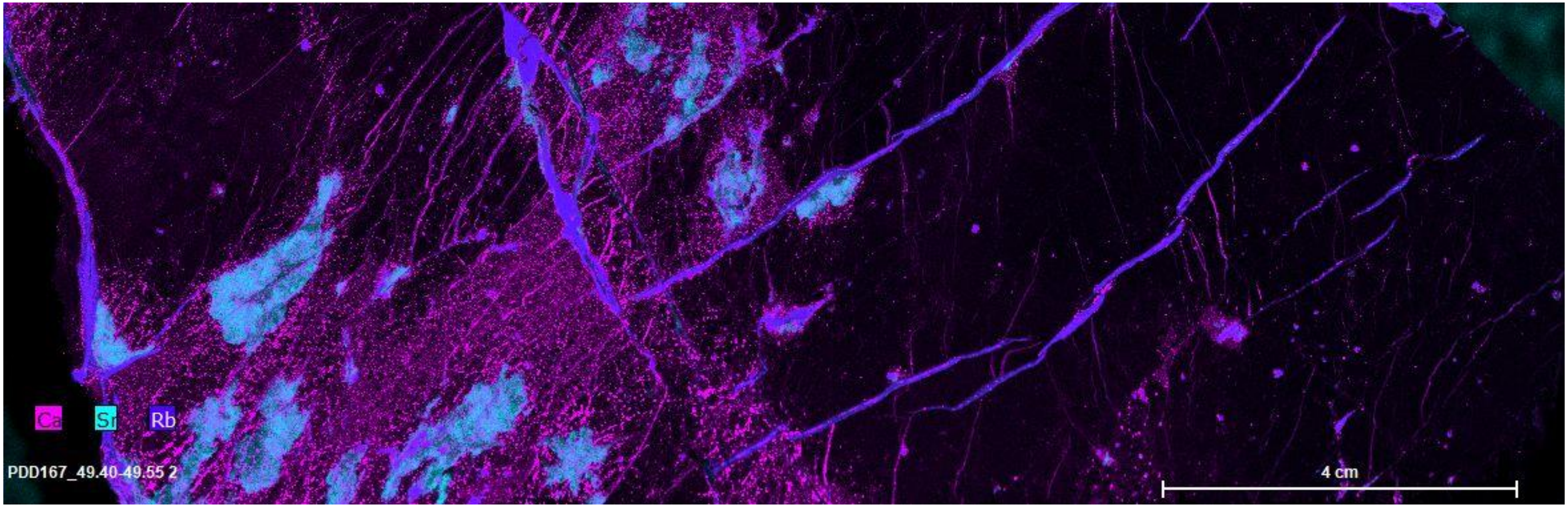
Ca



Fe



Ca-Sr-Rb



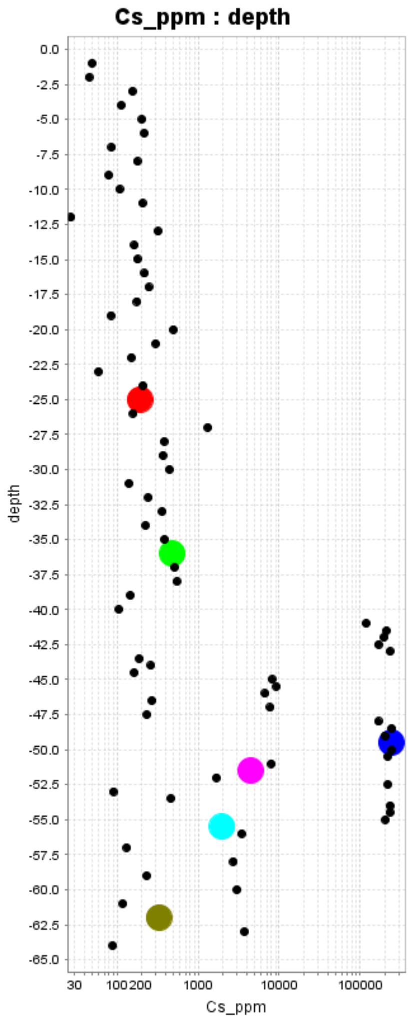
Summary

- Rapid, non-destructive technique
- Acquire qualitative and quantitative data at high spatial resolution
- Identify previously unknown minerals
- Detect chemical differences at the microscale
- Investigate the micromorphology, chemical variation and mineral alteration
- Element distribution and mineral maps for mineralogical discrimination

Questions

The non-destructive element mapping has been used on the Sinclair mine to determine:

Sample selection for micro-XRF scanning



- 25.30 to 25.50m: Microcline
- 36.40 to 36.60m: Albite
- 49.40 to 49.71m: Pollucite zone
- 51.80 to 52.05m: Amblygonite with lepidolite, qtz and albite mix zone
- 55.85 to 56.10m: Lepidolite zone
- 61.70 to 62.03m: Albite muscovite wall zone

Elemental Maps

Images of the 6 samples analysed – except don’t have images of all 6…
Heat map of Cs or something?

Elemental maps are used to confirm the geochemical model and provide further information on which minerals the caesium and rubidium is concentrated and how pollucite formed

Problem 1: Correlation of Cs and Rb – identified in same minerals

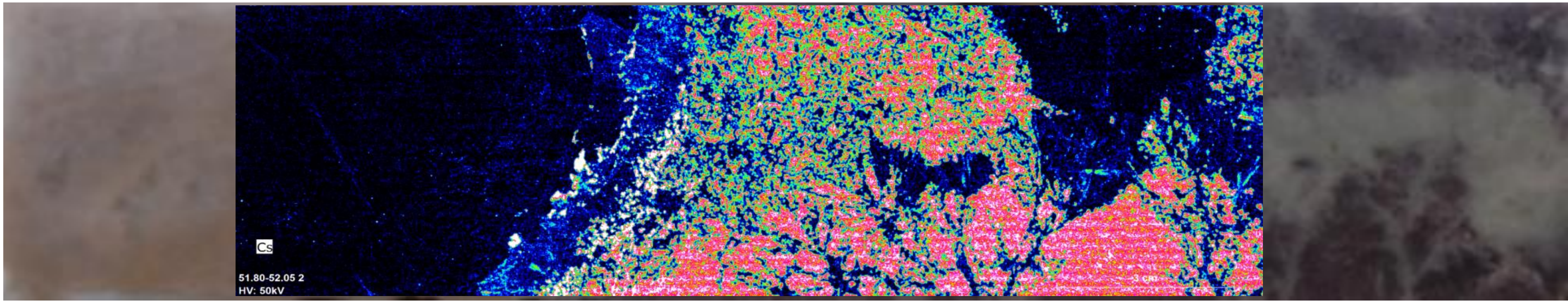
- Cs-Rb downhold using pXRF
- U-XRF analysis of Cs and Rb rich sample
- Rb in microcline – hydrothermal overprint (wave of alteration through the sample)

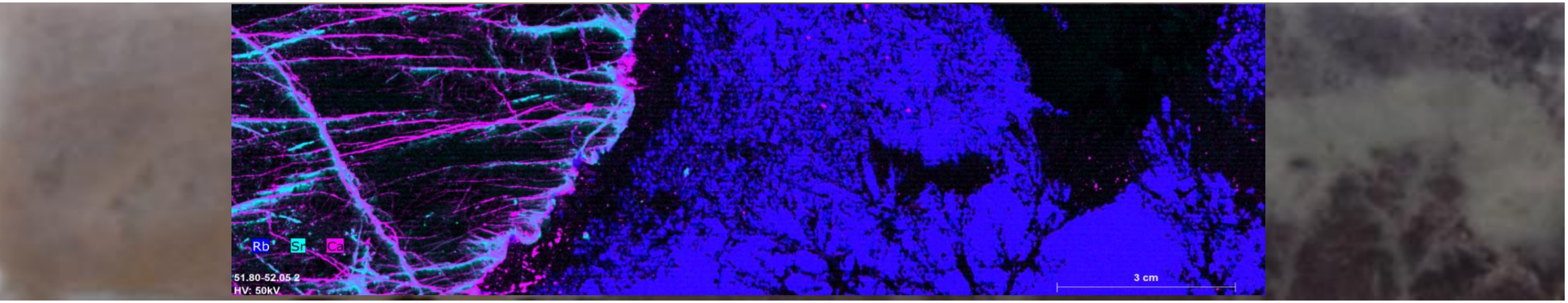
PDD167: 51.80 - 52.05m: Amblygonite with lepidolite, qtz and albite mix zone

Cs (bulk analysis 0.42%)

Rb (bulk analysis 1.03%)

Cs within the lepidolite





Incredible mapping of penetrating and cross cutting Ca-Sr & Ca veinlets.

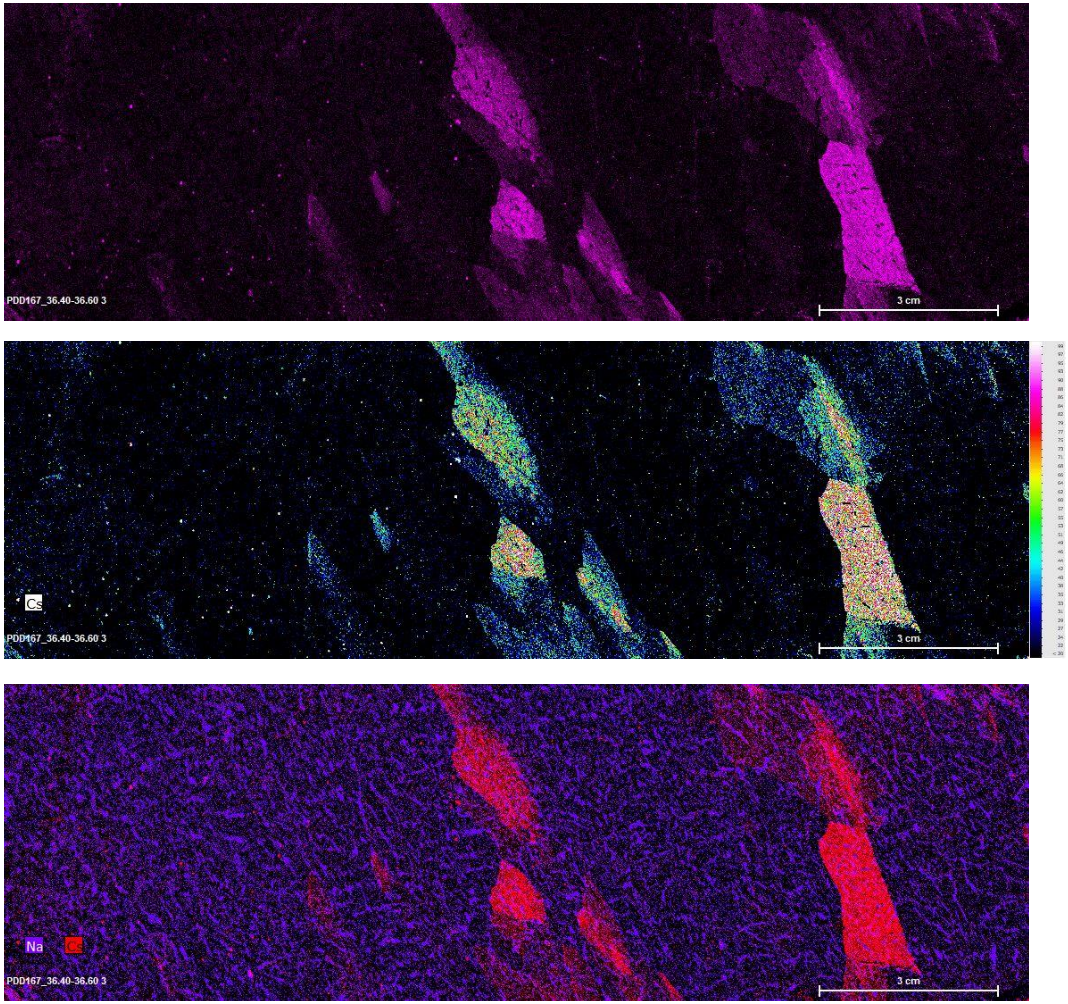
Rb within the lepidolite

Problem 2: Formation of pollucite (Cs-rich)

- Pollucite – PDD167: 49.4-49.7
- PDD167: 36.4-36.6 m
- Movement of elements through the lepidolite veins

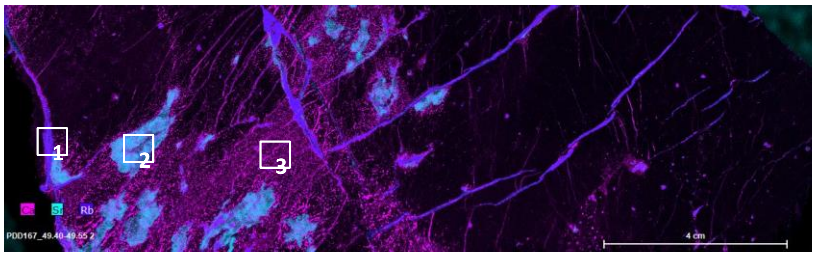
PDD167: 36.4-36.6

Cs - Na

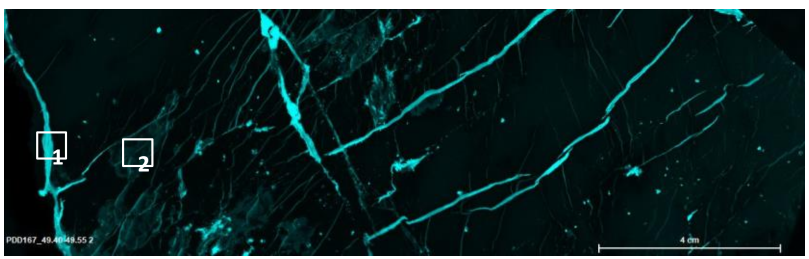


Cs not replicating the rock texture and appears show two band moving through the sample distributed - alteration front?

PDD167: 49.40 to 49.71m

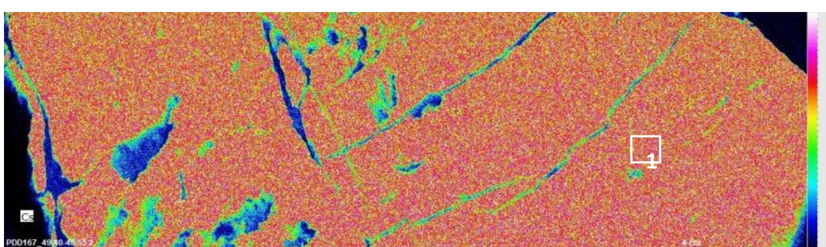


1. Rubidium mapping out lepidolite views
2. Strontium mapping out anhedral albite
3. Calcium mapping out "albite" pseudomorphs



Rubidium mapping out

1. veins of lepidolite
2. Ghosting "albite" fabric

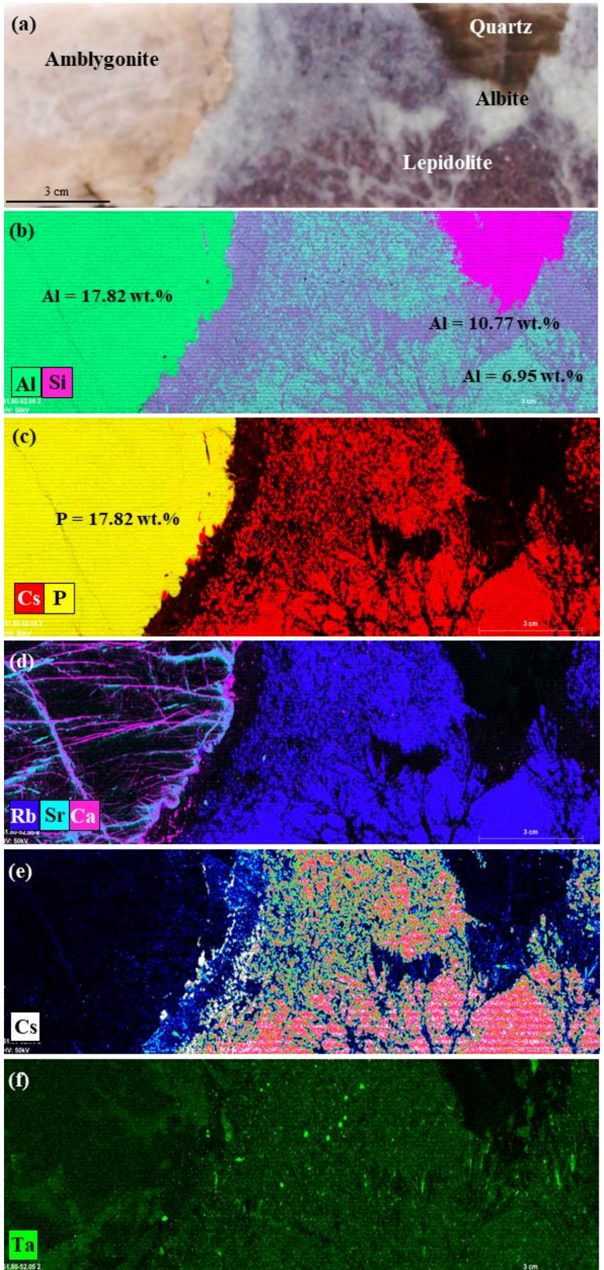


Caesium pervasive through put the sample of pollucite
Low concentrations in the lepidolite veinlets and "albite"
NOTE elevated Cs in the Fe veins (1)

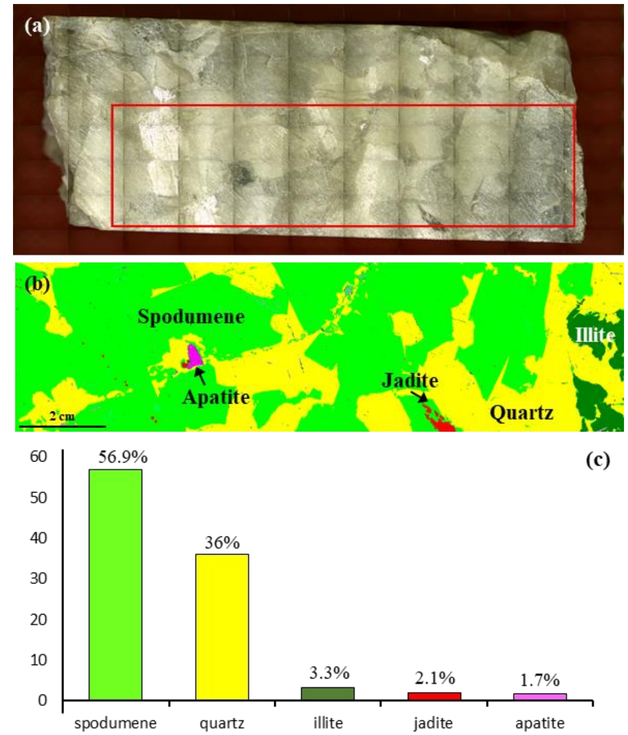
Summary

Micro-XRF in LCT pegmatites

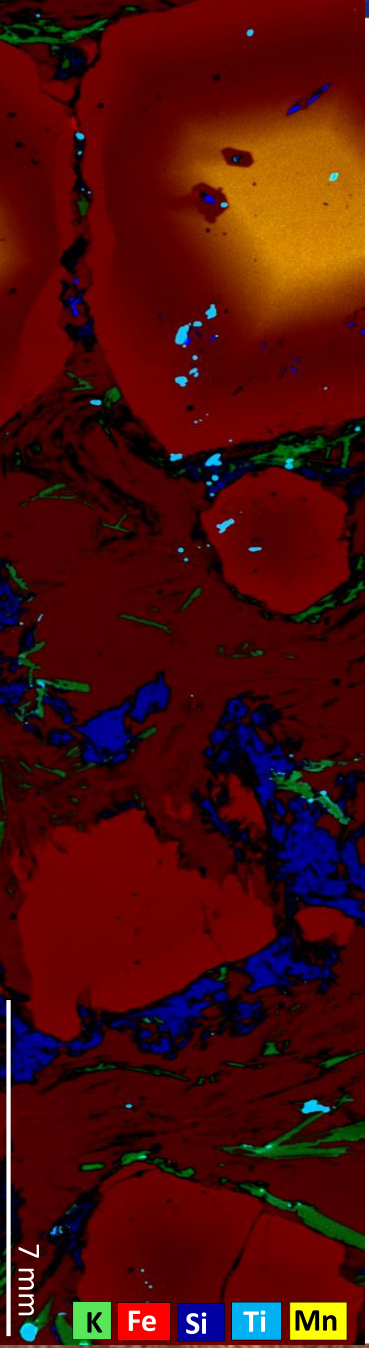
- **No need for any thin sections** for confirmation of the mineral system and modal minerology.
- Cesium is present in high quantities as a **primary mineral** and occurs in the microcline zone. This is used to constrain the exploration model.



(a)
Amblygonite
Quartz
Albite
Lepidolite
3 cm
(b)
Al = 17.82 wt.%
Al = 10.77 wt.%
Al = 6.95 wt.%
Al
Si
(c)
P = 17.82 wt.%
Cs
P
(d)
Rb
Sr
Ca
(e)
Cs
(f)
Ta



(a)
(b)
Spodumene
Illite
Apatite
Jadite
Quartz
2 cm
(c)
60
50
40
30
20
10
0
56.9%
36%
3.3%
2.1%
1.7%
spodumene
quartz
illite
jadite
apatite

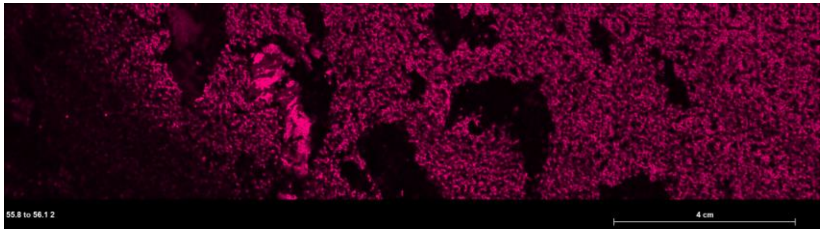


Micro-XRF Summary

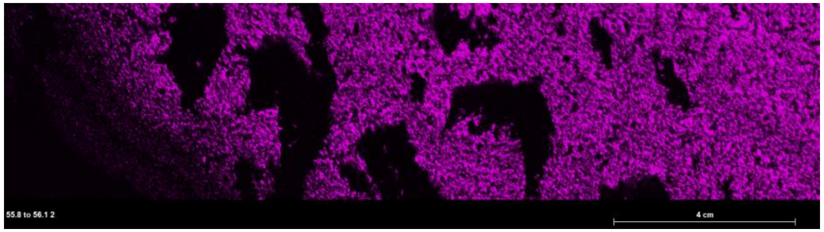
- Non-destructive technique
- Rapid analysis with minimal sample preparation
- Element composition and distribution with ‘on-the-fly’ measurements
- High resolution element distribution maps

PDD167:55-56 Lepidolite

Cs



Rb



25.30 to 25.50m: Microcline
good quality mirocline with some green sericite coating fractures and rare green muscovite rare black specs of manganese
Mineralogy (asd): phengitic illite

36.40 to 36.60m: Albite
white chalky albite breaking down to clay with green sericite very broken zone
mineralogy (asd): phengitic illite

49.40 to 49.71m: Pollucite
high grade pollucite zone with lepidolite veinlet texture rimmed by blue cleav greasy lustre appearance >20% Cs Bruker pXRF
Mineralogy (asd): pollucite

51.80 to 52.05m: Amblygonite with lepidolite, qtz and albite (cleavendite)
mix zone - large amblygonite crystals 0.25m long with lep/qtz/cleav –
Mineralogy (asd): aspectral

55.85 to 56.10m: Albite – lepidolite
lepidolite zone with rich blue albite (cleavendite) some qtz –
Mineralogy (asd): paragonite and kaolinite

61.70 to 62.03m: Albite, muscovite
Albite muscovite wall zone - some accessory garnet tormaline blue speck ?sodalite
Mineralogy (asd): muscovitic-illite

Chemistry:

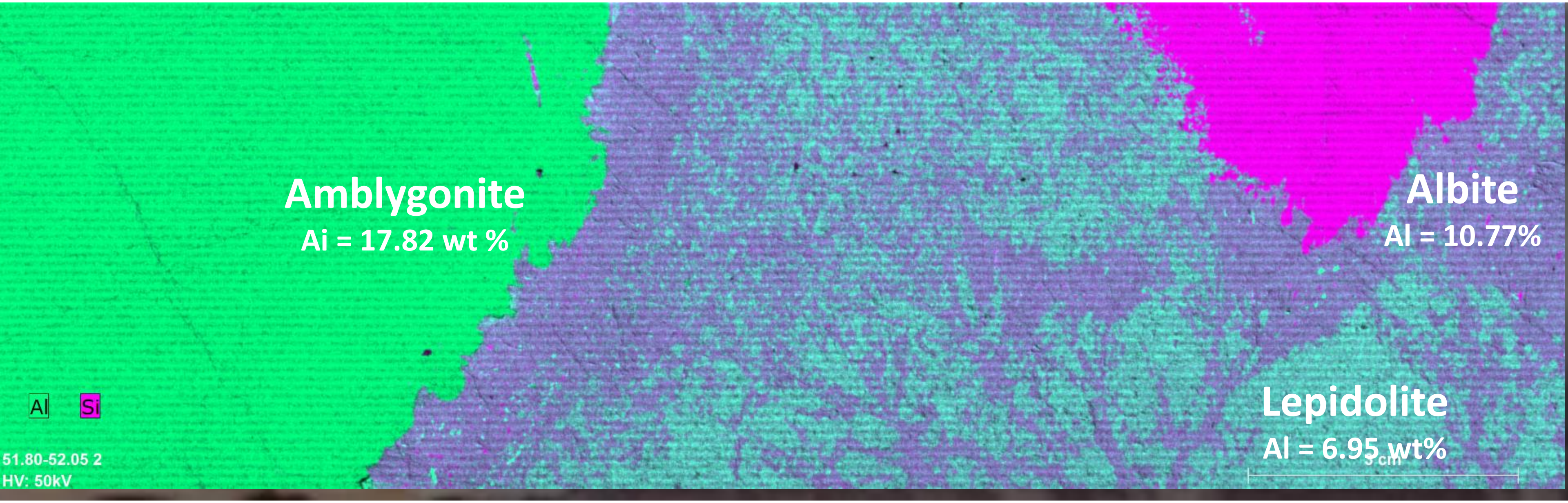
Sample ID	from	to	SampleID	Al2O3 pct	Ba ppm	CaO pct	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cs ppm	Cu ppm	Fe pct	Ge ppm	K2O pct	La ppm	Li ppm	MgO pct	MnO pct	Na2O pct	Nb2O5 pct	P2O5 pct	Rb2O pct	Sb ppm	Se ppm	Sn ppm	Sr ppm	Ta ppm	Te ppm	Zn ppm	Zr ppm	Lith_Plot
PDD167_051	50.76	51	ARC112714	12.73	2.2	0.029	0.01	0.005	0.3	2	4177.88	1	0.17	12.4	4.616	0.02	9144.6	0.03	0.064	2.59	0.011	0.06	1.124	1.12	0.25	151.3	4.49	187.16	0.1	4	16.8	Gp9

M4 Mapping:
PDD167: 51.80 - 52.05m

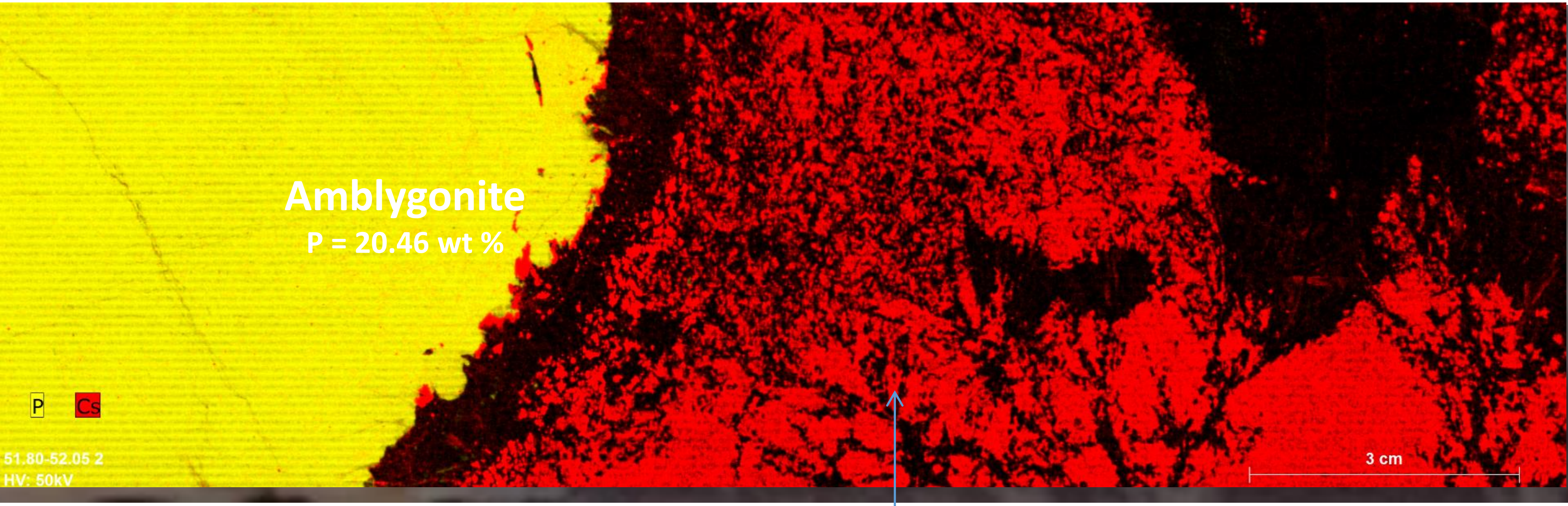
Prelim results

PDD167: 51.80 - 52.05m

PDD167: 51.80 - 52.05m: Al (bulk analysis 6.74%)

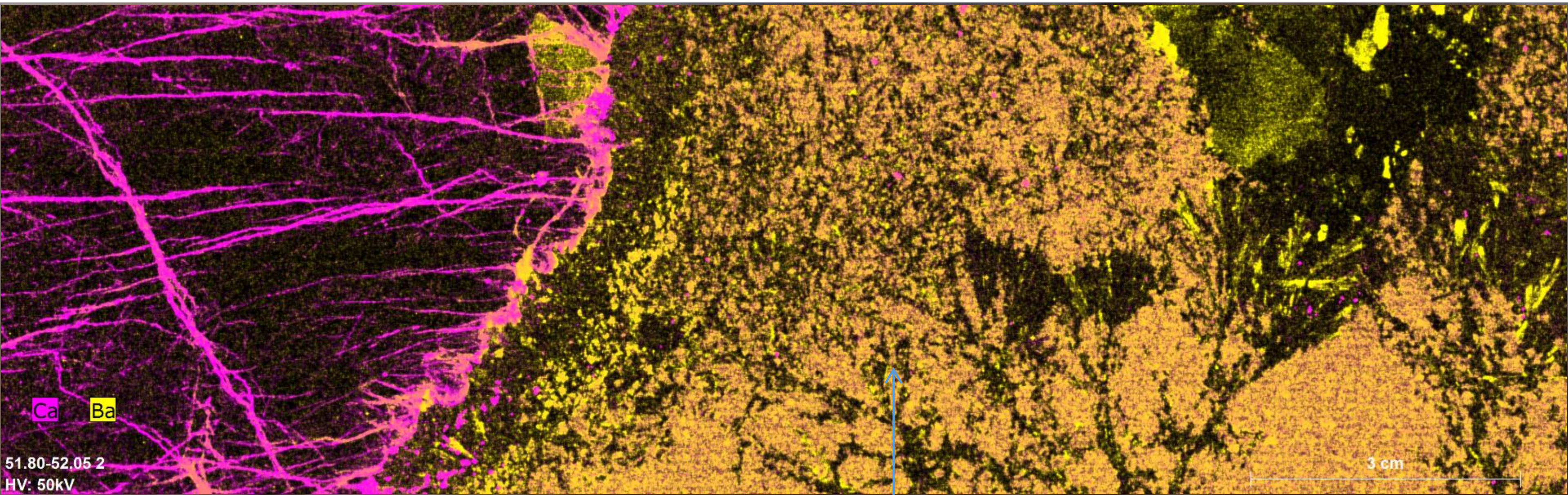


PDD167: 51.80 - 52.05m:
P (bulk analysis 4.7%); Cs (bulk analysis 0.42%)



Cs within the lepidolite

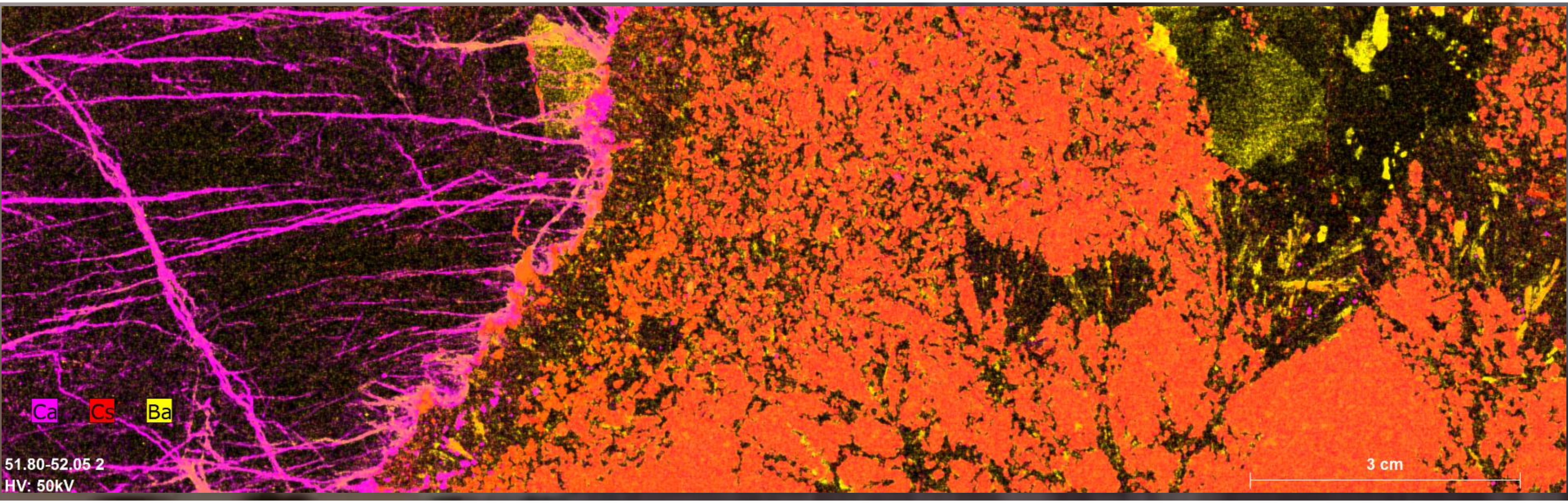
PDD167: 51.80 - 52.05m:
Ca (bulk analysis 0.15%); Ba (bulk analysis 2 ppm)



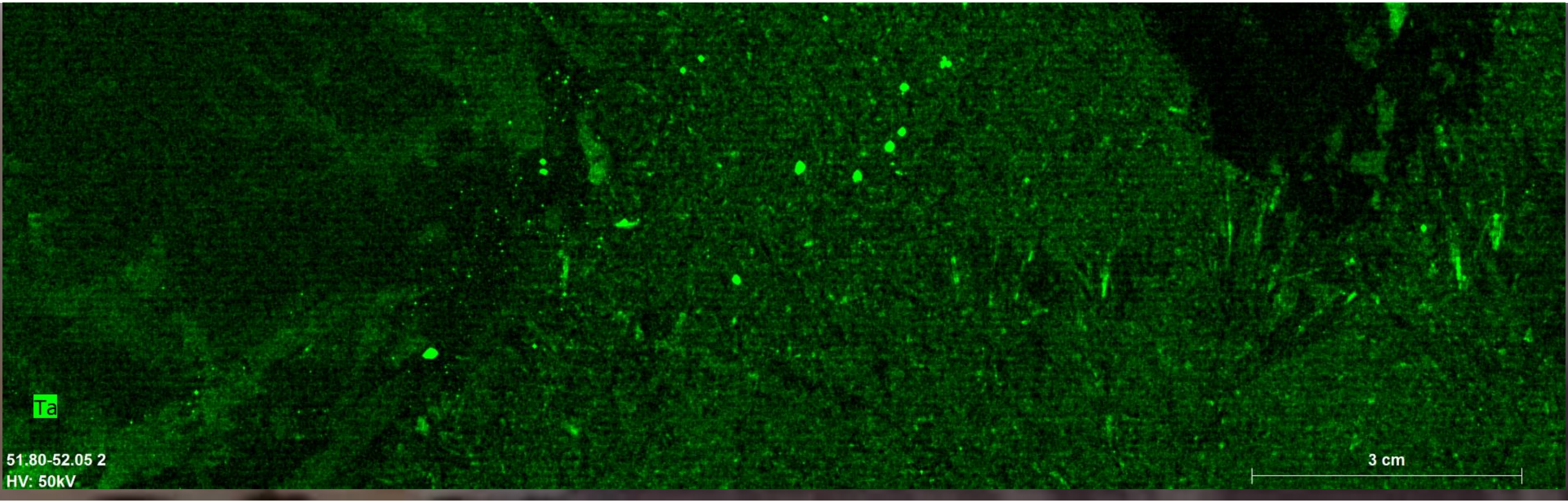
Incredible mapping of penetrating and cross cutting Ca veinlets.

Not convinced of Ba presence (Cs L-lines?)

PDD167: 51.80 - 52.05m:
Ba (bulk analysis 2 ppm)

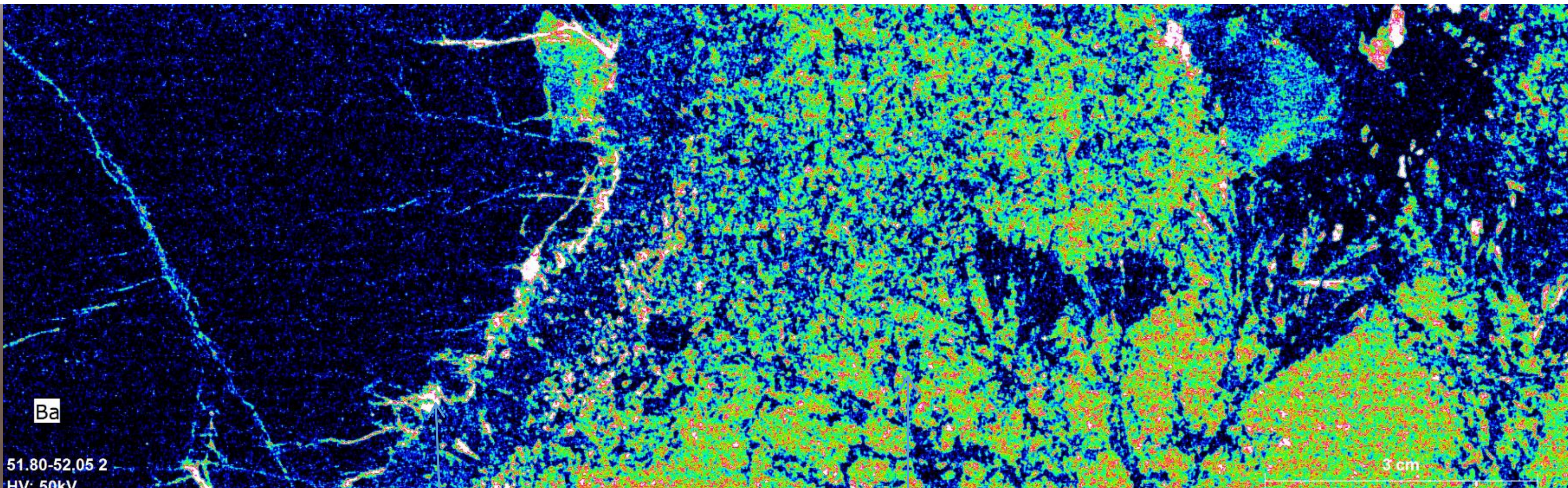


PDD167: 51.80 - 52.05m:
Tantalum (bulk assay = 187 ppm)



Discrete Ta phases (nuggets) associated with the lepidolite

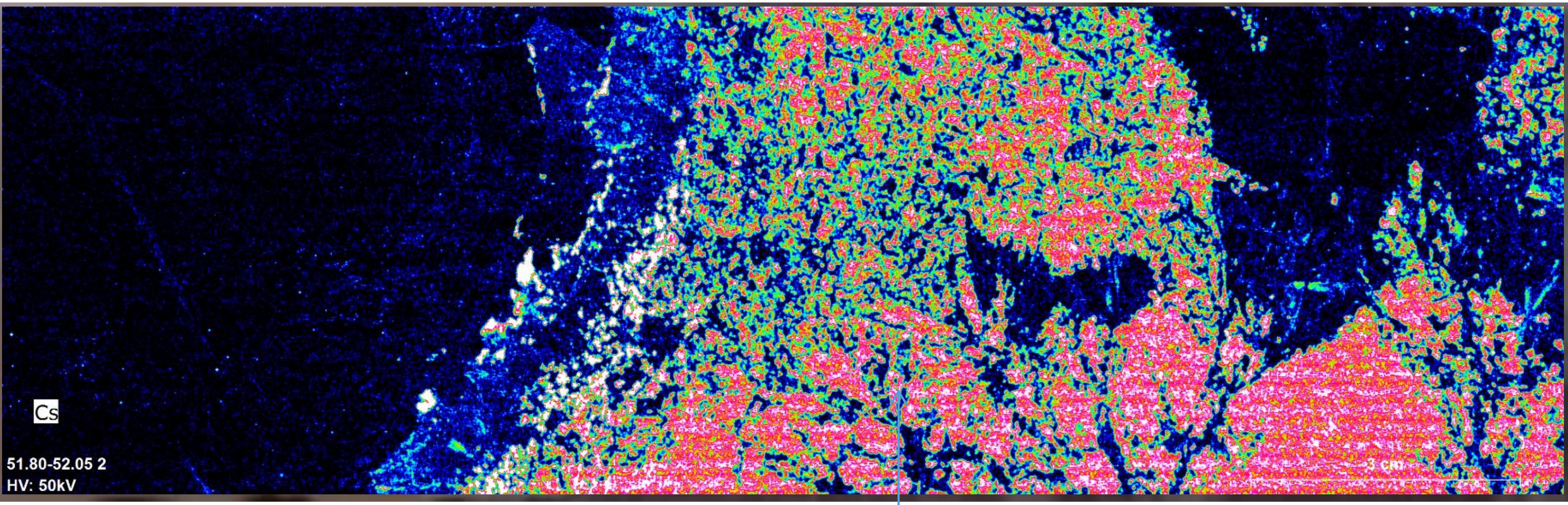
PDD167: 51.80 - 52.05m:
Ba (bulk analysis 2 ppm)



Ba on the phase boundary

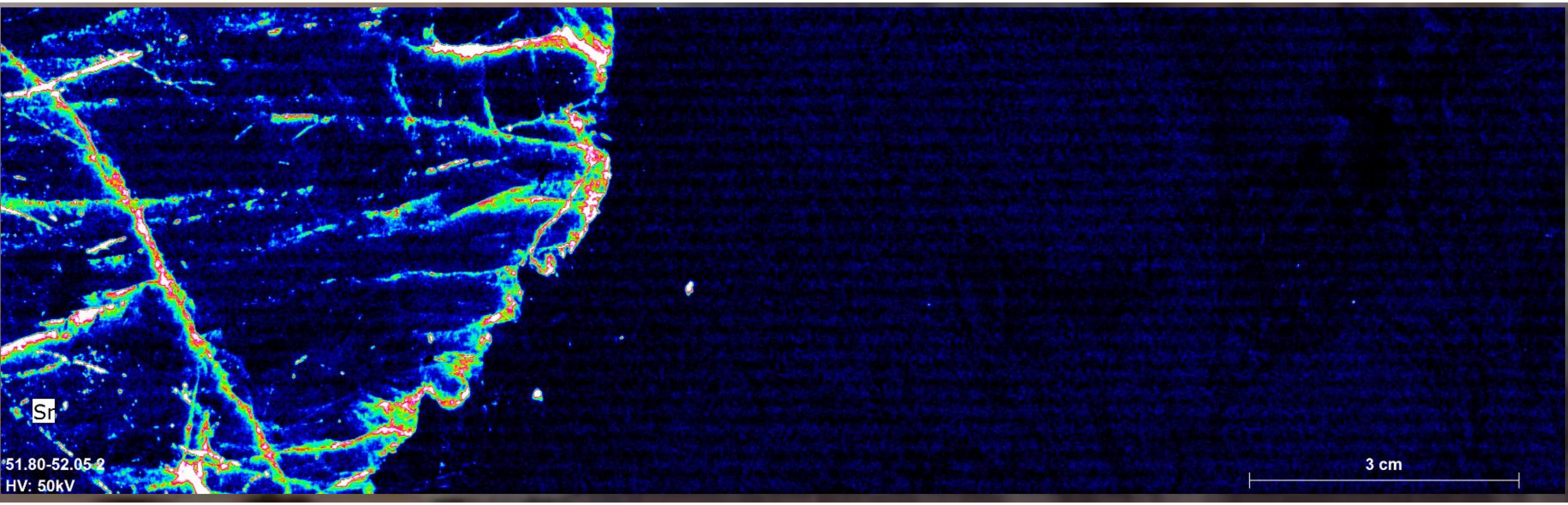
Not convinced of Ba presence (Cs L-lines?)

PDD167: 51.80 - 52.05m:
Cs (bulk analysis 0.42%)



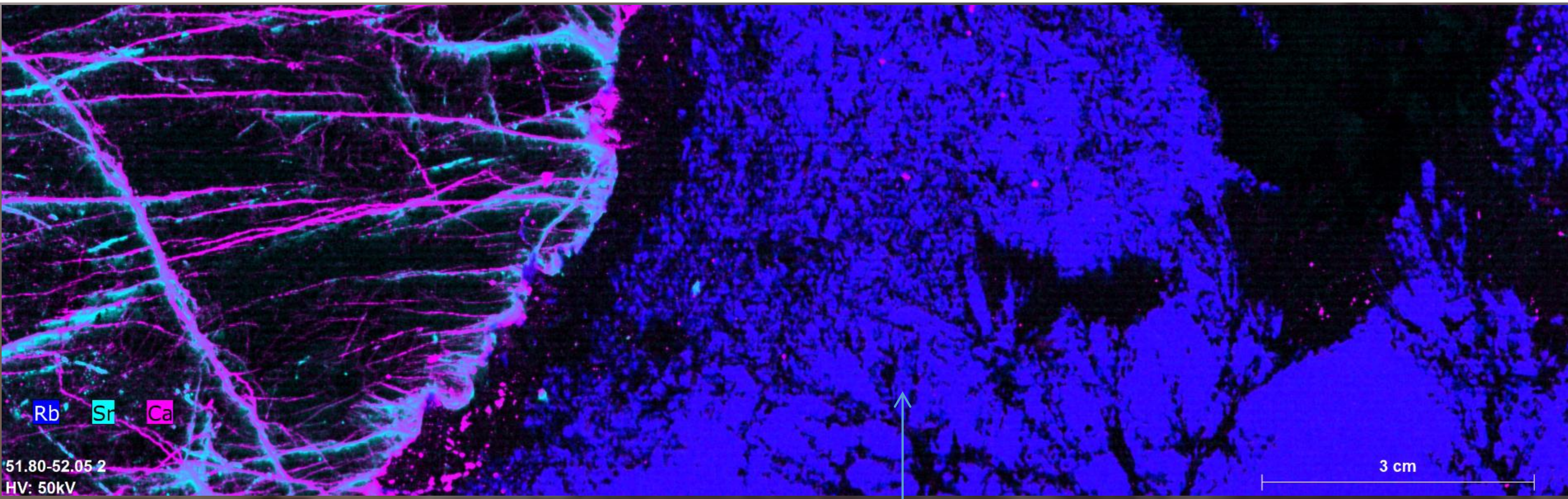
Cs within the lepidolite

PDD167: 51.80 - 52.05m: Sr (bulk analysis 74 ppm)



Incredible mapping of penetrating and cross cutting Sr rich veinlets.

PDD167: 51.80 - 52.05m: Rb (bulk analysis 1.03%)

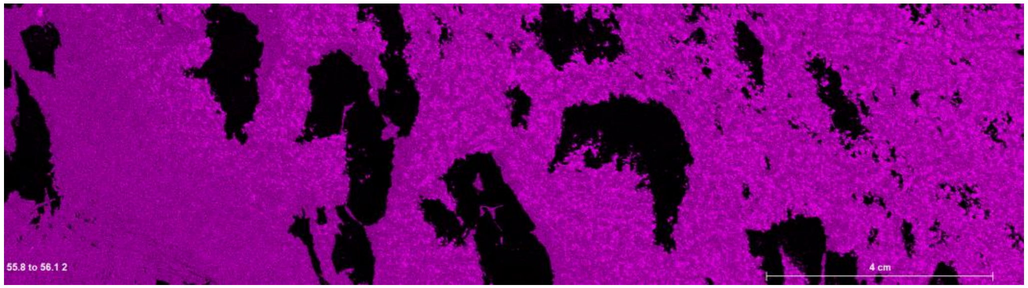


Incredible mapping of penetrating and cross cutting Ca-Sr & Ca veinlets.

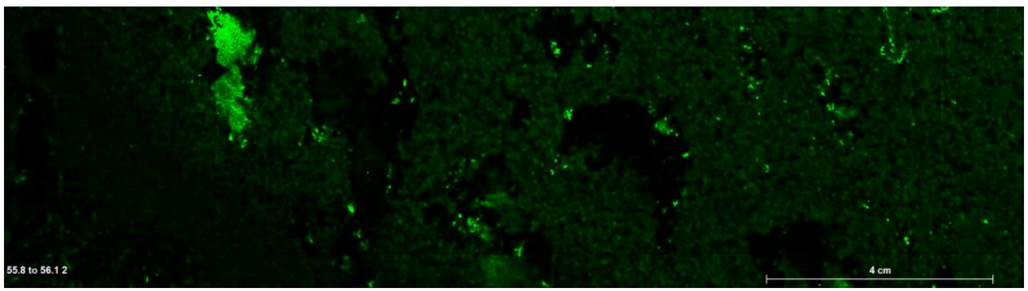
Rb within the lepidolite

PDD167: 55.85-56.10

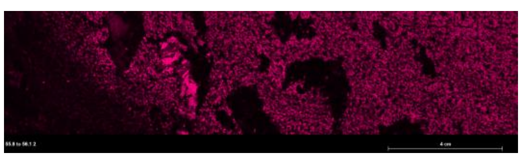
Al



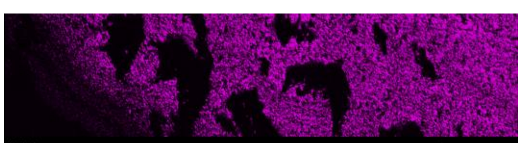
Ti



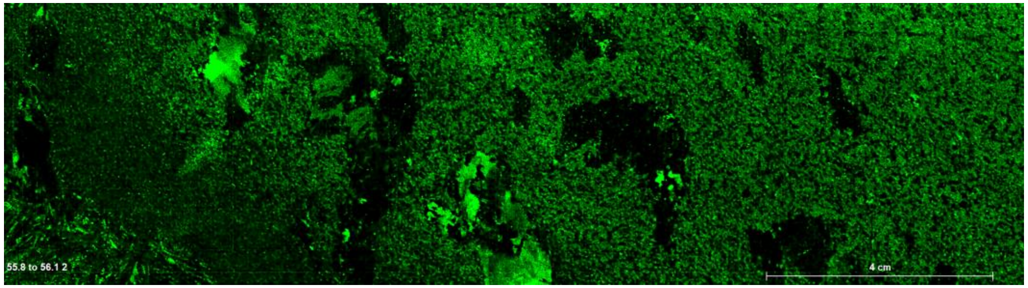
Cs



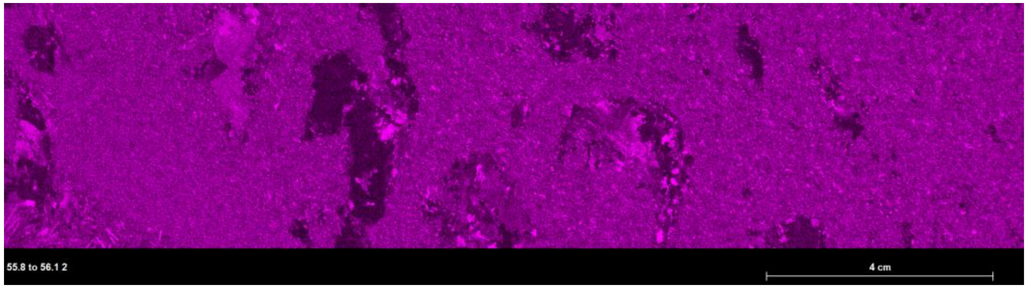
Rb



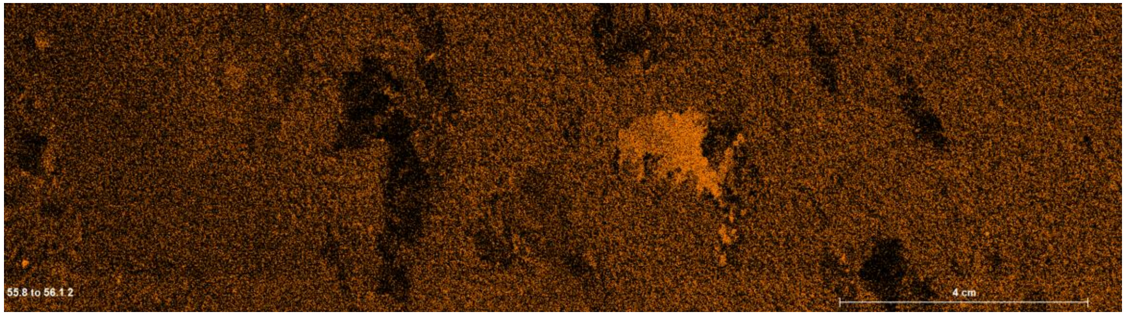
Fe



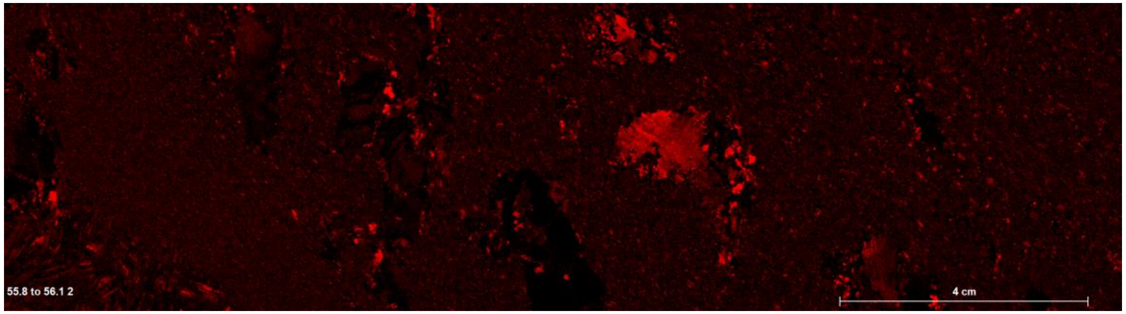
Ga



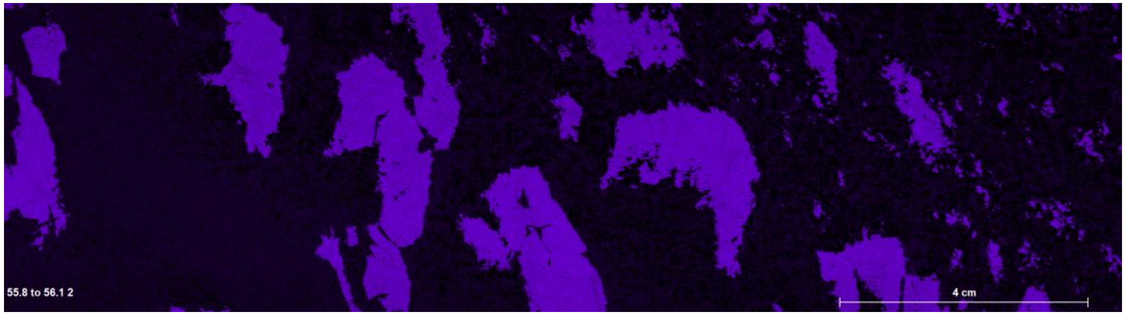
Sr



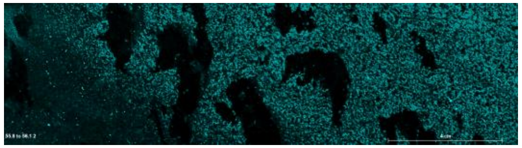
Zn



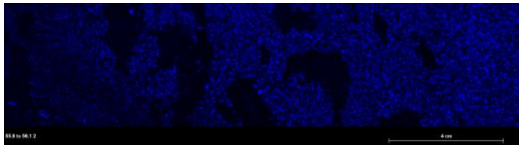
Si



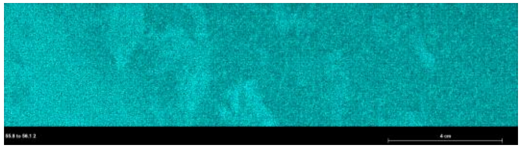
Ca



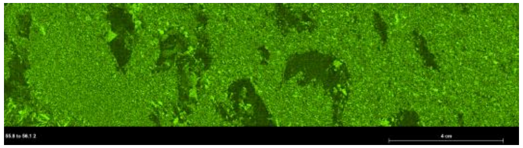
Cl



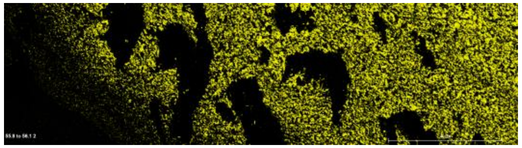
Nb



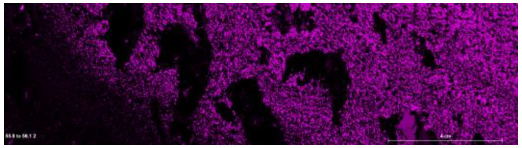
Ta



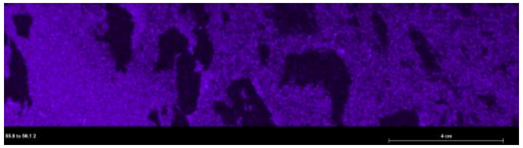
K



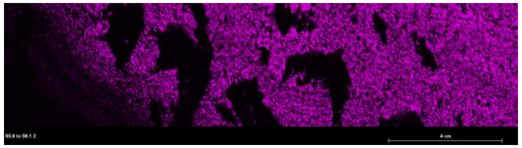
Mn



Na



Rb

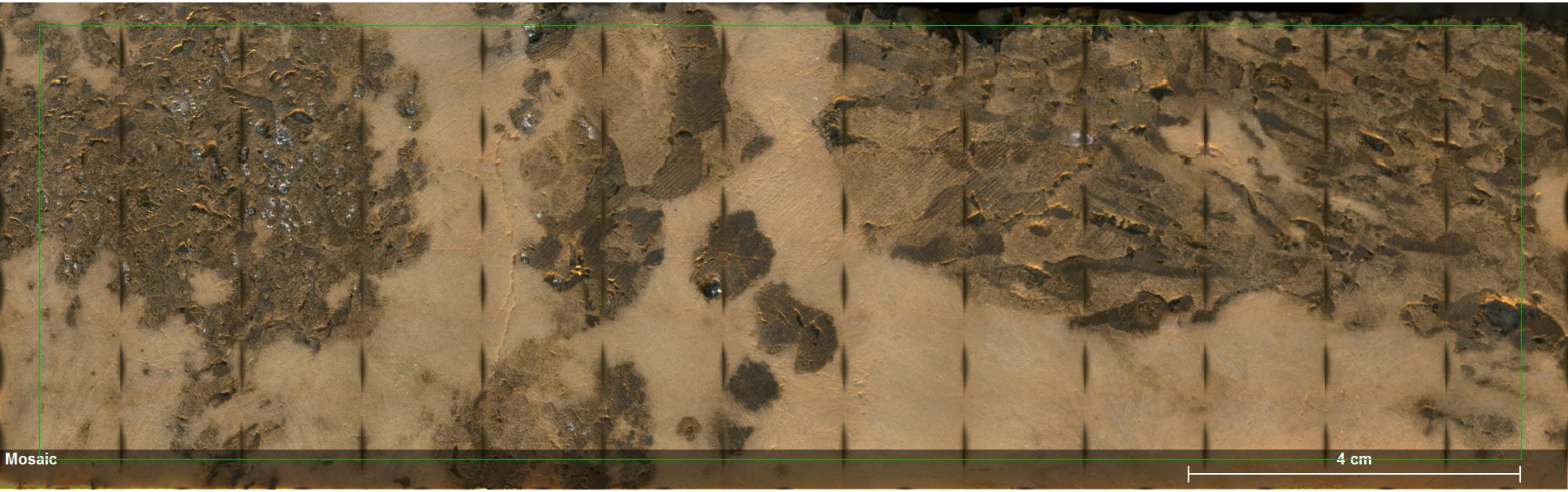


Sample ID	from	to	SampleID	Al2O3	Ba	CaO	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ge	K2O	La	Li	MgO	MnO	Na2O	Nb2O5	P2O5	Rb2O	Sb	Se	Sn	Sr	Ta	Te	TiO2	Zn	Zr	Lith_Plot
				pct	ppm	pct	ppm	ppm	ppm	ppm	ppm	ppm	pct	ppm	pct	ppm	ppm	pct	pct	pct	pct	pct	pct	ppm	ppm	ppm	ppm	ppm	ppm	pct	ppm	ppm	
PDD167_062	61	62	ARC112723	7.12	1.7	0.061	0.04	1.4	0.2	6	348.18	1.8	0.71	4.3	1.601	0.38	1239.9	0.01	0.091	4.947	0.011	0.02	0.115	1.2	0.25	31.7	1.76	22.12	0.1	0.01	164	11.7	Gp2

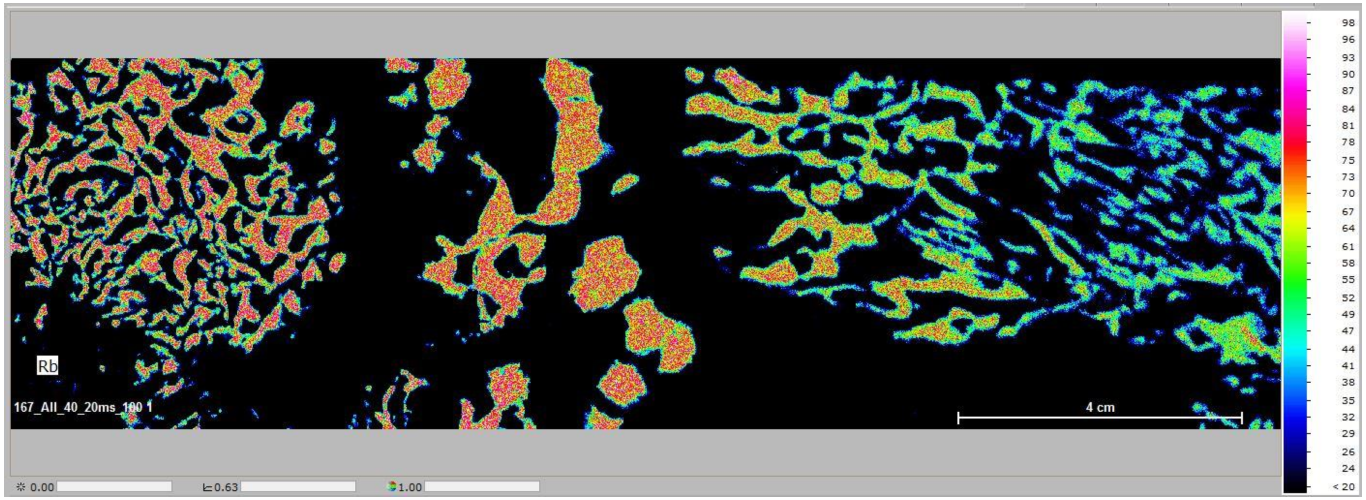
M4 Mapping: PDD167: 61.7-62.03 m

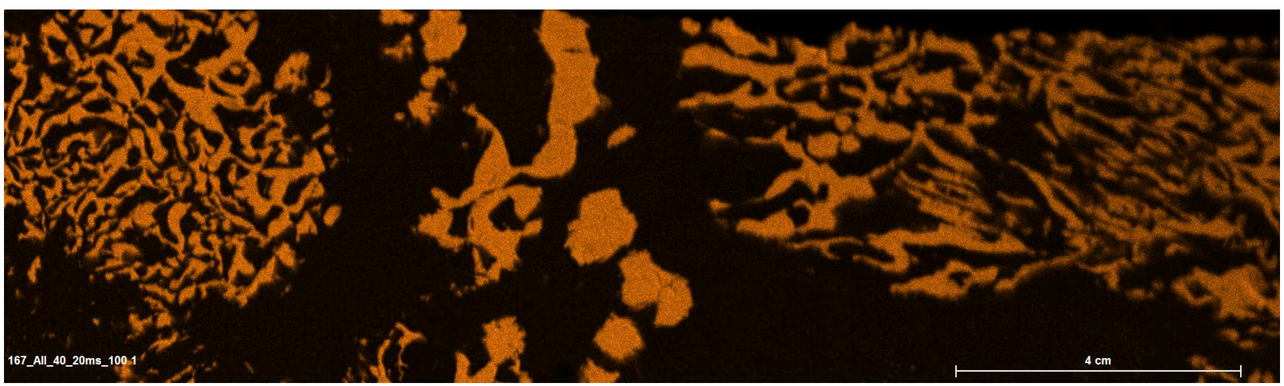
Prelim results

Image

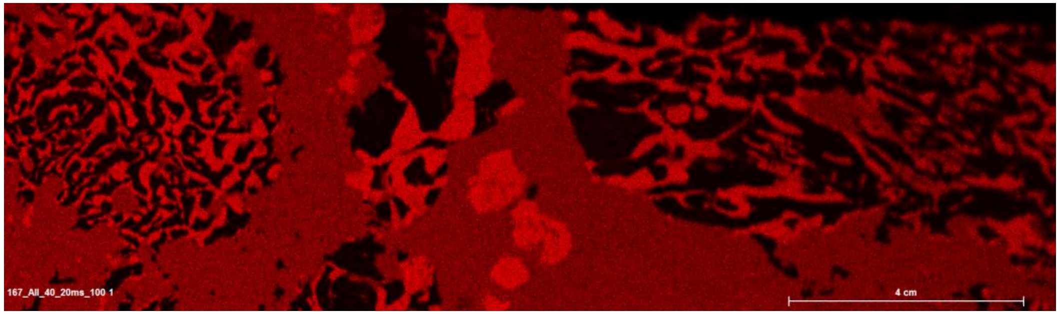


Rb

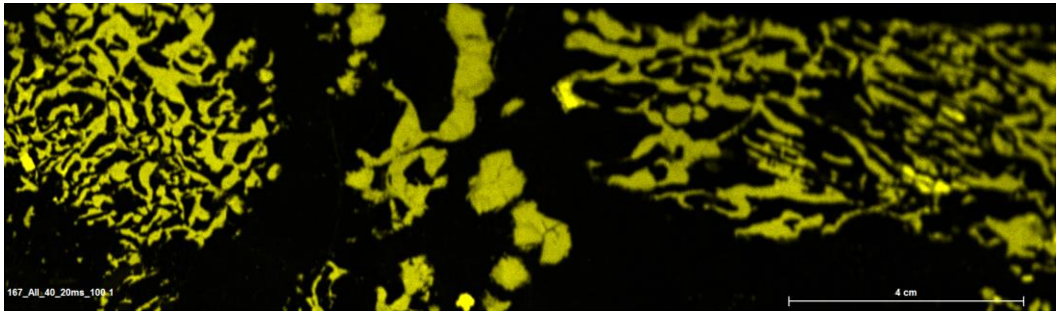

Rb
167_All_40_20ms_100 1
4 cm
98
96
93
90
87
84
81
78
75
73
70
67
64
61
58
55
52
49
47
44
41
38
35
32
29
26
24
< 20
0.00
0.63
1.00


167_All_40_20ms_100 1
4 cm

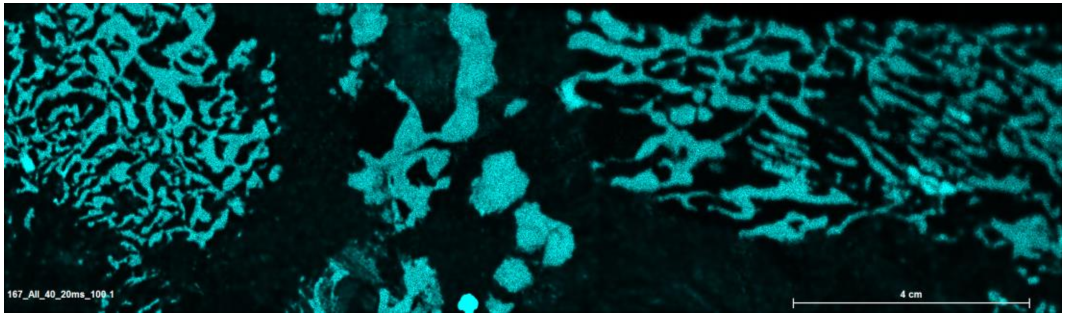
Al


167_All_40_20ms_100 1
4 cm

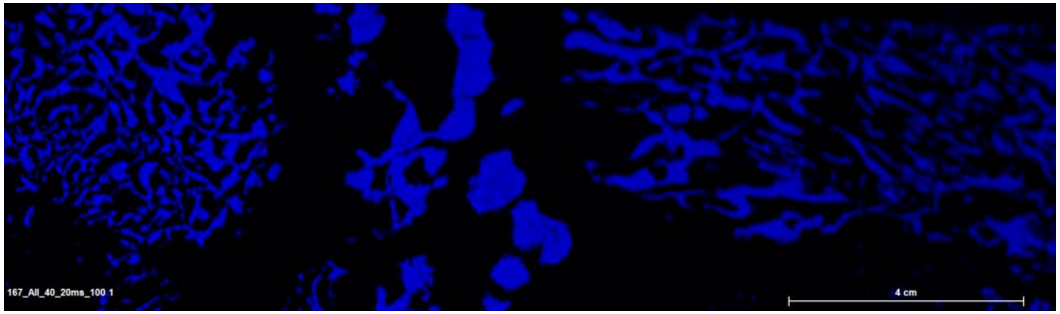
Fe


167_All_40_20ms_100 1
4 cm

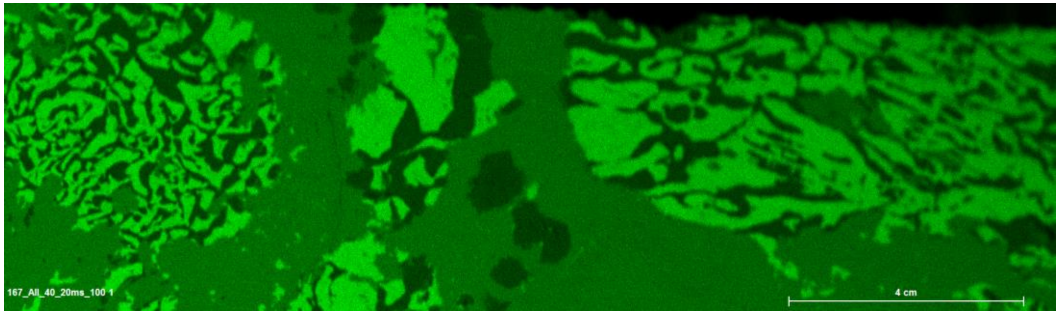
Mn


167_All_40_20ms_100 1
4 cm

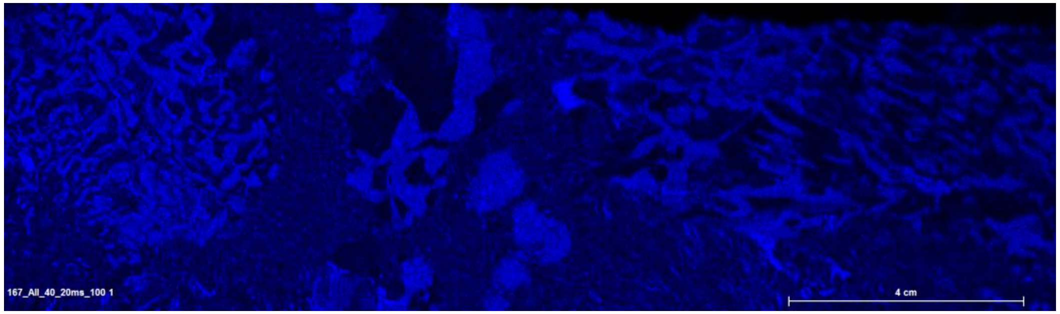
K


167_All_40_20ms_100 1
4 cm

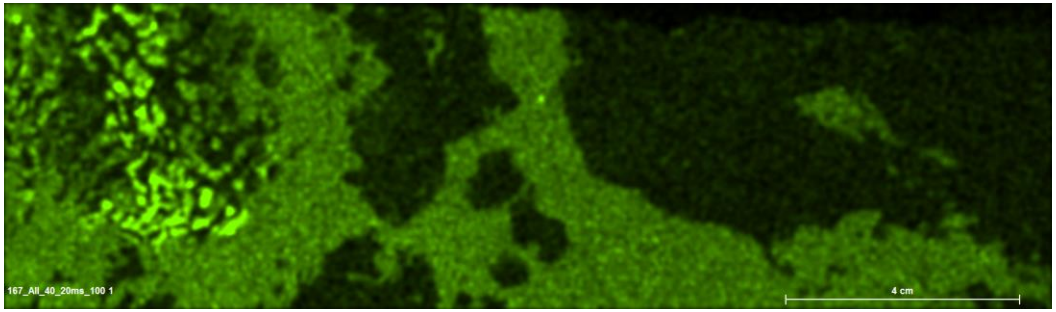
Si


167_All_40_20ms_100 1
4 cm

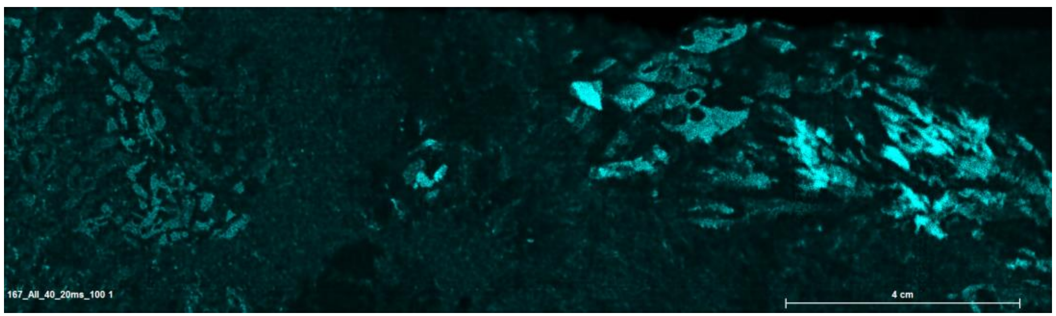
Zn


167_All_40_20ms_100 1
4 cm

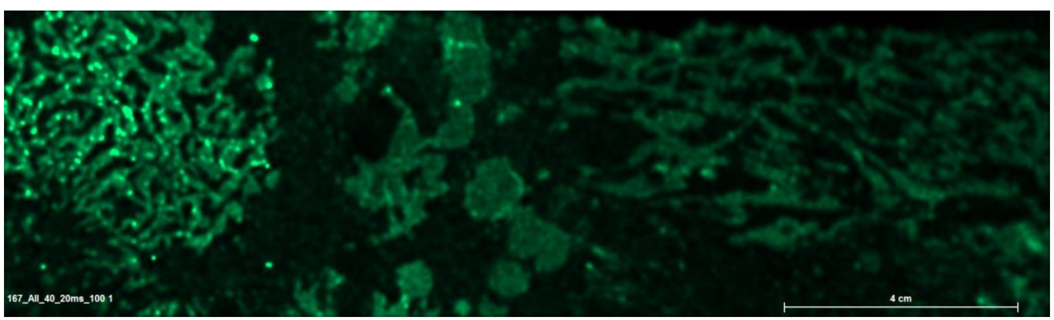
Na


167_All_40_20ms_100 1
4 cm

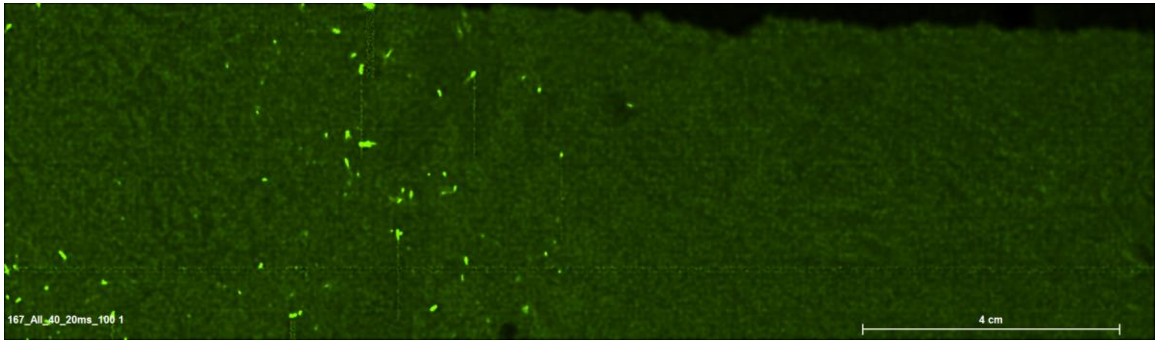
Cu


167_All_40_20ms_100 1
4 cm

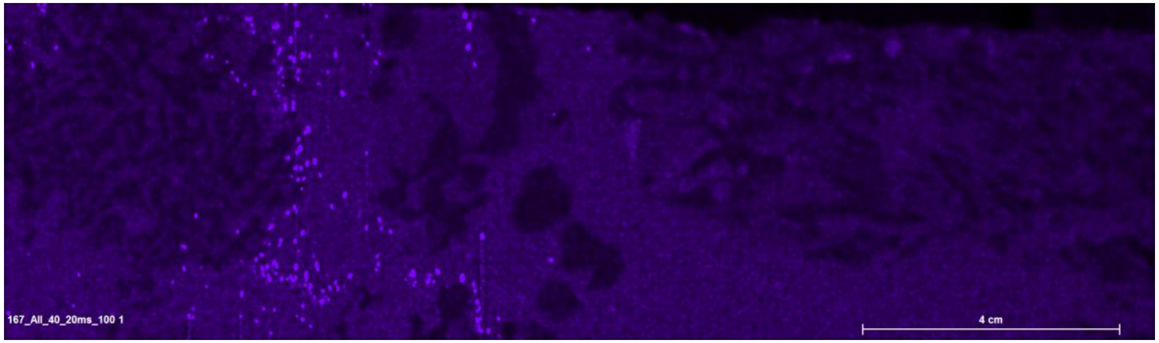
Cs


167_All_40_20ms_100 1
4 cm

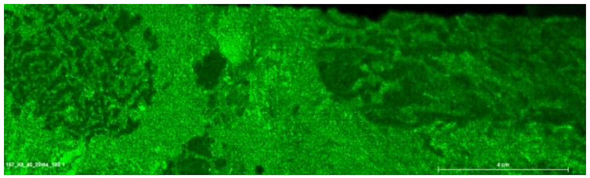
Nb



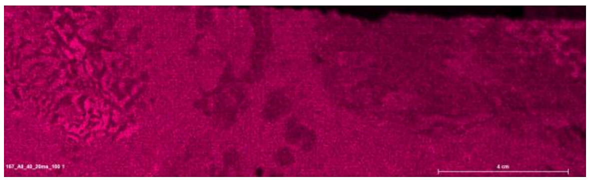
Zr



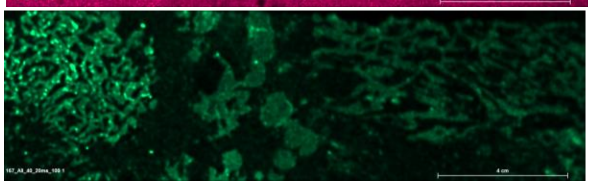
Ga



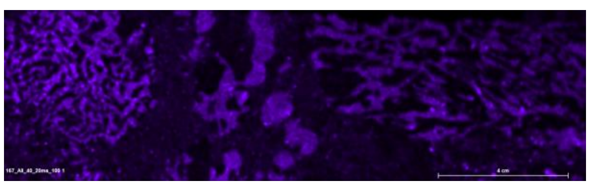
Sr



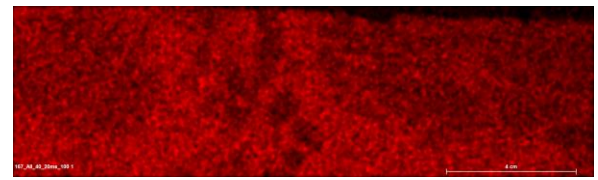
Cs



Ti



Sn



Ca